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EARLY PLANT SUCCESSION AFTER CLEARCUTTING OF  
LODGEPOLE PINE FORESTS IN THE LOWER FOOTHILLS  
OF ALBERTA

by



IAN GEORGE WILLIAM CORNS

A THESIS

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled 'Early Plant Succession After Clearcutting of Lodgepole Pine Forests in the Lower Foothills of Alberta' submitted by Ian George William Corns in partial fulfilment of the requirements for the degree of Master of Science.



## ABSTRACT

The main objectives of this thesis are (1) to describe the phytosociological and structural attributes of early secondary plant succession and tree regeneration after pulpwood clearcutting of mature *Pinus contorta* forest in the Lower Foothills Section of the Boreal Forest Region of Alberta; (2) to relate these community attributes to the environment; (3) to describe the flora and structure of mature lodgepole pine forests on adjacent uncut blocks and compare these to successional communities on clearcut blocks.

Mature lodgepole pine-dominated forests of the Edson study area are even-aged and being succeeded by black spruce, subalpine fir and white spruce. Aspen comprises up to one-half of the tree stratum. Shrub strata are poorly developed, herb-dwarf shrub strata dense and uniform, and bryophyte strata almost continuous.

One hundred vascular species were recorded in quadrats on 25, 6-12 year old clearcut stands.

Pine and aspen cover increased during the 6-12 year interval after clearcut contributing equally to all but 0.5% of the total tree regeneration cover of 7%.

Mean total cover of the shrub stratum in the clear-



cut stands was only 1%.

Mean total cover of the herb and dwarf shrub stratum was 50% accounting for over 80% of the total vascular cover. Nine common species of mature pine forest plus *Epilobium angustifolium* composed 37% of total cover on clearcut stands.

Mean total cover of the bryophyte lichen stratum was 13%, lichens comprising less than 1%. Lichen cover is increasing.

Mean total vascular cover was 58%, ranging from 39% to 102%. Analysis of variance revealed no significant differences for total vascular cover during the 6-12 year interval after clearcutting. Few species showed significant changes in cover or density between 6 and 12 years after clearcutting. However, some species greatly increased in cover, and total bryophyte cover decreased tremendously within two years after clearcutting.

A two-dimensional ordination of the 25 clearcut stands based on plant cover data revealed soil moisture and nutrient gradients correlated with variations in several species and habitat attributes within the stands.

The regeneration density has stabilized within 6 years after clearcutting. There were no significant differences among years for any species. Regeneration



mortality was greatest on the older stands but does not comprise a significant proportion of total stem density.

Above ground pine biomass increased from 40-70 kg/ha on 3 blocks cleared in 1964, to 1000-4300 kg/ha on three blocks cleared in 1958. Aspen biomass increased from 7-1800 kg/ha on the 1964 blocks to 500-6400 kg/ha on the 1958 blocks.

Clearcut blocks were classified on the basis of the relative abundance of the two principal grasses into a moist *Calamagrostis* type and a drier *Elymus* type, each with several indicator species.



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## I. OBJECTIVES

1

This study was undertaken with three main objectives in mind.

1. To describe and characterize the initial stages of secondary plant succession and tree regeneration after pulpwood clearcutting of mature lodgepole pine forests on a limited range of sites in the Lower Foothills Section of the Boreal Forest Region of Alberta, by quantitative sampling of structural and phytosociological attributes and plant production.
2. To relate these attributes to the environment.
3. To briefly describe the structure and floristic composition of the mature, undisturbed lodgepole pine forests in the same study area. Such descriptions provide controls and may enhance potential applications of results to other areas of similar forest.

It was beyond the scope of this study to give a detailed account of the climate, geology, soils, wildlife activity, and past history of the Lower Foothills lodgepole pine forests. Rather the intent was to concentrate on the initial stages of secondary plant succession following a specific type of pulpwood cutting operation.



## II INTRODUCTION AND LITERATURE REVIEW

### A. Succession and Silviculture

The Lower Foothills Section B19a of the Boreal Forest Region was described by Rowe (1959) as follows: "The distinctive tree species is the lodgepole pine (*Pinus contorta* var. *latifolia*) which, with aspen (*Populus tremuloides*) and balsam poplar (*Populus balsamifera*), has assumed a dominant position over much of the area in the wake of fire. In older stands the white spruce (*Picea glauca*) is an important constituent and black spruce (*Picea mariana*) is frequently present too. White birch (*Betula papyrifera*) and tamarack (*Larix laricina*) have scattered representation with the above species on appropriate well-drained or poorly-drained sites, respectively. Both balsam fir (*Abies balsamea*) and alpine fir (*Abies lasiocarpa*) are common locally in the main body of the Section, although the over-all importance of these species in the forests is small." Rowe's description of the dominant tree species of Section B19a applies to the Marlboro 7 study area north of Edson with the exceptions that *Larix laricina* was not evident even in low areas and *Abies balsamea* was not evident.

Little research has been done on secondary plant succession in the Lower Foothills area, especially as related



to clearcutting or other extractive forestry operations. Work on initial stages of lodgepole pine in Alberta with consideration to other than silviculturally important tree species is scarce. Cormack (1953) noted that as a rule in the Eastern Rockies, succession proceeded faster in the more open type of pine growth than in dense stands. Cormack's stage 1 (10-20 years after fire) is characterized by sparse mosses and lichens with a mixture of grasses, herbs, and several introduced species.

In a consideration of fire succession in North-western Alberta, Rowe (1961) cited Plochmann who suggested the most important effect of fire is on the moisture regime of the surface soil: dry sites are made drier and wet sites are made wetter. These site differences are obscured under the climax forest and sharpened following fire. Perhaps the most favorable effect of fire is the destruction of the raw humus, making the burn more receptive to regeneration. Clearcutting a forest may have a similar effect (Maini and Horton 1966).

Most logging succession studies in western North America have related to the Douglas fir and Sitka spruce forests of Washington and Oregon, where site conditions, floristic composition, secondary plant succession and tree regeneration are very different from those in the Alberta



Foothills. These marked ecological differences probably account for post harvest treatment differences between the two regions (eg., burning of slash in the Pacific North West vs. lopping and scattering of slash in Alberta).

Isaac (1943) reported that in the Douglas fir region of Washington and Oregon, there is generally a luxuriant development of shrubby and herbaceous ground cover after logging. This shrub and herb cover is temporarily reduced to almost nothing by the subsequent slash burning procedures. The roots of several understory species may survive the logging treatment and together with other invading herb and shrub species commonly create a dense growth over two meters in height. The rate of development of the herb and shrub cover depends upon site quality, slash fire intensity, repeated burns, species present and annual weather variations.

Isaac reported that 19 herb species made up over 90% of the total cover on slash-burned plots. He observed a gradual decrease in herb cover and a gradual increase in shrub cover until the eighth year when there were equal parts of both. Annuals (eg., *Senecio vulgaris*) come in promptly after logging and slash burning and may form 90% of the ground cover, but may disappear in a single year. West and Chilcote (1968) observed a very similar successional pattern on a Douglas-fir clearcut area in the Oregon coast range.



Isaac noted that *Epilobium* spp. do not come in as quickly but last longer. *Epilobium angustifolium* and *Lathyrus* spp. usually increase in density for a period of 3 to 5 years and then start to decline. Practically all the common herb and shrub species will invade cut-over land whether the slash is burned or not, but burning has a definite influence on the rate of development and distribution. Yerkes (1960) reported findings similar to those of Isaac, on old-growth Douglas-fir clearcuts in the Oregon Cascades.

Studies in Western Canada particularly east of the Rocky Mountains, deal primarily with stocking adequacy of pulpwood species and give little attention in most cases to herbaceous and shrubby vegetation and to currently desirable tree species. Foresters have made frequent attempts to find methods to increase seedbed receptivity to conifer seeds (Crossley 1952a, 1956a; Waldron 1966; Hughes 1967; Lees 1970). The current consensus is that this objective is best accomplished by a mechanical scarification treatment disturbing the humus layer and baring mineral soil. A mechanical scarification to produce a favorable seedbed and to reduce fire hazard is especially suited to lodgepole pine, because if the logging slash is burned, an overstocked condition may result (Crossley 1956a). Horton (1953) reported that for a large 16 year old burn on the Kananaskis



Forest Experiment Station in Alberta, 25% of the area was heavily overstocked and stagnating and an additional 23% was lightly overstocked and would probably stagnate in the future. He concluded that overstocking was the usual tendency on better sites after fire. Crossley (1956a) found, for a dry clearcut stand near Strachan, Alberta, that the only acceptable degree of stocking to lodgepole pine resulted after scarification and that very favorable results were obtained by exposing only one fifth of the seed bed. He observed that most pine regeneration occurred in the first growing season after cutting though germination in the second year was also considerable. Crossley also stated that germination probably continues for several years but will probably just keep pace with seedling mortality which is high during this period.

Excessive moisture appears to hamper abundant regeneration and survival. High water table areas under muskeg in Northern Alberta produce sparsely stocked stands of lodgepole pine (Smithers 1961). Lack of aeration and limited rooting volume appear to be the causes for the low survival of pine on these areas (Smithers 1961).

The method of harvesting the pine trees should affect the success of the subsequent forest regeneration and the trends of plant succession on the logged area. During the late 1800's and early 1900's selective cutting for railroad ties and poles was widely practiced in the lodgepole pine



stands of the Alberta foothills. Edson became a center for tie hacking operations as new railroads created a new demand for ties (Smithers 1961).

Partial cutting to a diameter limit (eg., 12 inches for ties) can be justified only if this practice allows regeneration of the stand or if the remaining smaller diameter trees show a release and stand volume increment in accordance with the potential of the stand (Smithers 1961). Blyth (1957) made a thorough investigation of partial cutting of pine in western Alberta in low density stands and concluded that diameter growth of residual stems was not stimulated, that pine regeneration was unsatisfactory, and that a continuation of partial cutting would likely result in the conversion of the present pine stands into a scrub-aspen type.

Crossley (1952b) described a clearcutting experiment in a 73 year old residual pine stand in the Alberta foothills which had been lightly burned in 1936. The stand was clear-cut in 1942 in 40.4 m (two chain) strips separated by a 20.2 m uncut strip. A regeneration survey done in 1951 showed an acceptable stocking of 60% on the clearcut stand and 16% in the uncut. He suggested that the success of the experiment was due in part to droughty soil conditions which restricted litter accumulation and vegetation density.

Crossley (1955a), in a report on several cutting



methods on the Strachan Experimental Block in Alberta, stated that scarification was necessary to achieve satisfactory regeneration. Superiority of clearcutting in regenerating an area was apparent, seedbed preparation being more thorough by more intensive logging.

The lodgepole pine clearcutting operation of North Western Pulp and Power at Hinton results in varying amounts of lopped pine boughs or slash lying on the ground. Logging slash is an important seed supply for subsequent pine regeneration but it can also be a fire hazard, slash disposal must therefore be a compromise between the requirements of seed supply and fire hazard control (Smithers 1961). Both of these objectives can be accomplished by a mechanical scarification of the ground surface.

A study of the effects of some stand and seedbed treatments on lesser vegetation in a boreal Ontario mixed wood (Sutton 1964) showed that treatments not involving disruption of unincorporated organic matter in the logged area effected little change in species composition of lesser (herbaceous) vegetation on fresh sites. Most of the variation in amount and composition of lesser vegetation was attributed to changes in canopy density and seed availability. Treatments involving disturbance of unincorporated organic matter developed a significantly different flora from that of the control. In this case, practically all pre-existing



vegetation was removed with the organic matter using a root-rake, exposing mineral soil over most of the treated area. *Polytrichum juniperinum* was an aggressive invader the first year, followed quickly by light-seeded biennials and light-demanding perennials. Sutton noted that the treatment most favorable to coniferous reproduction appears to be one which provides a mineral soil seedbed and opens the canopy slightly if at all, while retaining coniferous seed trees. It should be noted here that pines were absent in the tree stratum, the dominant conifers being the more shade tolerant white spruce and balsam fir. Seed fall is also much heavier under white spruce than under lodgepole pine (Crossley 1955b).

#### B. Site Classification

In order to be acceptable a site classification must show strong correlations with vegetative "productivity" and take into account successional trends and reproductive capacities (Smithers 1961).

Duffy (1965a) investigated the relationships between physiographic site factors and growth of lodgepole pine near Rocky Mountain House, Alberta, and stated that where soil-site relationships with pine growth are sought, age and stocking level should be held constant as much as is practicable. He stated that age is the main factor affecting



growth, although density or stocking level must also be considered. Duffy stressed the difficulty of determining if a site is fully stocked for a given site condition.

Hills (1952) also used a physiographic approach to the classification and evaluation of site for forestry. Physiographic features are used as a frame of reference because these are stable and remain easily recognizable while other factors may change. Features emphasized are parent material, soil moisture, and local climate.

A considerable amount of work has been done using different plant species as indicators of a specific habitat.

Cajander (1926), a Finnish worker, constructed one of the first forest type classifications based upon lesser vegetation. He was able to distinguish dry moss, moist moss, and grass-herb forest classes, each class consisting of several types named on the basis of the dominant understory species of moss, lichen, herb or shrub. Different site types differ markedly in terms of current and mean increment of the tree diameter. Cajander mentioned also the problem following clearcutting hardwood types where dense weedy vegetation invades, competing severely with young tree seedlings. He observed that on land burned and cropped, or on areas burned after forest fires or tree felling, that in 7 to 8 years the number of invading vascular species reached a maximum of about 105. After this time, competition is



greatest and "biologically weaker" species gradually disappear. In 20 to 40 years the number of species declined to about 70, and after 60 years to about 40 species. A levelling off occurs after about the 70th year with the number of vascular species being between 30 and 40.

Brinkman (1931) related lichens to forest site values. He found in the Alberta foothills that lichen species having predictive value correspond closely to those described by Ilvessalo in Finland (in Brinkman 1931). *Cladonia* spp. *Cetraria islandica* and *Stereocaulon paschale* generally characterized poorer forest sites. Indicator lichens were frequently absent on the best sites.

Duffy (1965b) recognized productivity classes (ht. at 80 ft.) for white spruce using soil series, soil drainage, and characteristic moss, herb, and shrub species in Alberta mixedwood forest. Parent materials and soil drainage were however regarded as most important in a precise forest land classification.

Heringa and Cormack (1953) tabulated the occurrence of 39 species on different soil types in even aged pine stands in central Alberta. Distinct preferences of certain species were evident.

Coile (1938) questioned the hypothesis that ground vegetation reflects the quality of site better than trees and



that forest types are independent of floristic composition, age, and density at a given time. He did concede that plant indicators may be of limited use.

Rowe (1962) stated that after careful study of an area it was generally possible to produce a reasonably good site classification based upon a three-way correlation between key indicator plants, topographic-moisture gradients and forest growth. He emphasized though, that some minor species may not reflect conditions of importance to deeper rooted trees.



### III DESCRIPTION OF THE STUDY AREA

#### A. Location

Stands were located 32 to 39 km NW of Edson, Alberta, on the Hudson's Bay Oil and Gas Field Road. The study area was within Compartment VII, the Marlboro working circle, of the North Western Pulp and Power Ltd. timber lease.

All stands were located between  $116^{\circ}33'$  and  $116^{\circ}42'$  west longitude and  $53^{\circ}45'$  and  $53^{\circ}51'$  north latitude. All stands were within townships 55 and 56 range 18 W5 and township 56 range 19 W5.

Stand locations are shown on the accompanying map of the study area (Figure 1) (McLeod Watershed).

#### B. Climate

The Edson climatic data presented in Table 1 probably closely approximates the climate of the study area. Elevation difference between Edson and the study area is not great (936.1 m vs. 1030 to 1160 ASL). Climatic data from Mayberne Forestry Lookout located 8 km N of the study area would probably overestimate precipitation to some extent and show a depression in mean maximum and minimum summer temperature due to its higher (1470m ASL) elevation. Also, climatic data for Mayberne are available for only May through October.



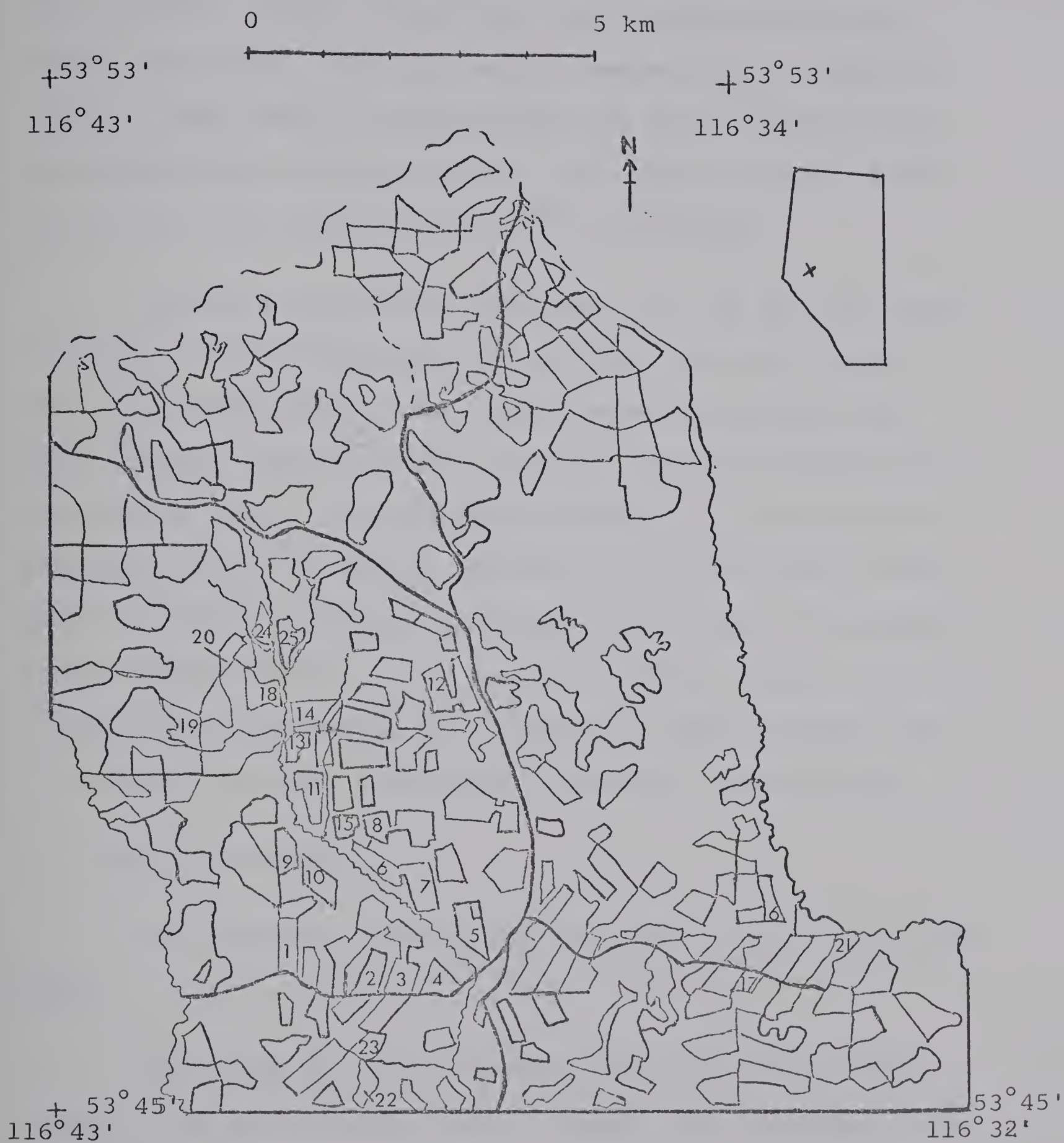


FIGURE 1. MARLBORO WORKING CIRCLE, COMPARTMENT 7,  
WITH STAND LOCATIONS



The climate is continental with cold winters and warm summers, though temperature can drop below freezing during any month. The mean annual temperature at Edson is  $35.3^{\circ}\text{F}$ . Mean monthly temperatures are above freezing for the months April through October, the highest being  $58.7^{\circ}\text{F}$ . in July and the lowest being  $8.4^{\circ}\text{F}$ . in January.

Annual precipitation averages 53.0 cm (20.85 inches) one-half of which falls as rain in June, July and August. Early afternoon showers are common especially during the early summer, and measurable rainfall occurs on nearly half the days of June, July and August (Table 1), but soon evaporates due to the drying influence of the westerly winds. Heavy rainfalls accompanying thunderstorms are not uncommon in the summer months. Soil erosion is not a serious problem in the study area due to the relatively gentle slopes, and is confined to steep unvegetated slopes as on road cuts.

### C. Surficial Geology

The following description is taken largely from Roed (1968).

The study area was situated upon what Roed (1968) refers to as the Interior Plains region. It is divided into: tablelands, benchlands, lowlands and buried valleys. Tablelands are characteristic of the higher elevations in the

Table 1.LEGEND

- a - 30 year normals (1931-60) from  
Meteorological Branch, D.O.T.  
Monthly Record (1970)
- \* - Amount insignificant
- b - 20-year normal (1941-60)

TABLE 1. Summary of Climatic Data For Edson Alberta

Edson Lat. 53° 35' N. Long. - 116° 25' W. Elev. 936.1m A.S.L.

	J	F	M	A	M	J	J	A	S	O	N	D	Year
Mean Daily Temp (°F) <sup>a</sup>	8.4	13.8	23.6	37.2	48.2	53.9	58.7	56.2	48.7	38.4	23.5	12.5	35.3
Mean Daily Max (°F) <sup>a</sup>	18.7	26.1	35.9	50.2	62.3	67.5	73.0	70.6	62.6	51.2	33.4	21.5	47.8
Mean Daily Min (°F) <sup>a</sup>	-1.9	1.4	11.2	24.1	34.0	40.2	44.4	41.8	34.8	25.5	13.6	3.4	22.7
Max Temp <sup>a</sup>	55	66	72	86	90	98	100	92	88	84	69	62	100
Min Temp	-55	-48	-42	-30	8	25	25	25	-1	-14	-34	-54	-55
Mean Rainfall (in.) <sup>a</sup>	0.02	0.02	0.07	0.38	1.97	3.59	3.66	3.16	1.48	0.37	0.17	0.09	14.98
Mean Snowfall (in.) <sup>a</sup>	9.8	7.3	8.8	6.8	0.8	0.0	0.0	0.0	1.5	6.1	8.6	9.0	58.7
Mean Total (in.) <sup>a</sup>	1.00	0.75	0.95	1.06	2.05	3.59	3.66	3.16	1.63	0.98	1.03	0.99	20.85
Days meas. rain (70.01 in) <sup>b</sup>	*	*	*	3	9	14	15	13	9	4	1	1	69
Days meas. snow (70.1 in) <sup>b</sup>	7	6	5	4	1	-	-	-	1	3	5	6	38
Days meas. precip.	7	6	6	7	10	14	15	13	11	6	6	6	107
Max precip. in 24 hrs	0.80	0.80	0.70	1.80	2.13	3.11	2.58	3.00	1.46	1.26	1.40	0.70	3.11



region (e.g., Mayberne Tower). No stands were located on tablelands. Benchlands are not physically well-defined and are modified considerably by glacial erosion. Some benchland terraces such as the Athabasca River valley are free of gravel.

Lowlands are of low relief and are of low elevation relative to the benchlands and tablelands. They are underlain by deposits of gravel, till, and glaciolacustrine sediments resting on a bedrock surface of low relief. Gravel can occur beneath the glacial deposits on top of the bedrock. This gravel layer is believed to have been deposited by glacial or non-glacial streams during the formation of the Edson lowland (Roed 1968). The sampled lodgepole pine stands occur mainly on the benchlands and to a limited extent on the lowlands.

The study area is underlain by the Paskapoo formation, a bedrock consisting of weakly consolidated sandstone, siltstone and shale of the Paleocene Age (McCrossan and Glaister in Roed (1968)). Beds of large size cobbles and gravels overlies Paleocene sediments on tablelands.

#### D. Soils

Soils found within the study area are predominantly of the Luvisolic Order. They are moderately well to imper-



fectly drained and have developed under forest growth from generally acidic parent materials. Luvisolic soils are characterized by a light-coloured eluviated horizon (Ae) and by darker horizons in which clay has accumulated. The Luvisolic soils of the study area are of the Gray Wooded Great Group. Subgroups represented include: Orthic Gray Luvisols, Bisequa Gray Luvisols, and Brunisolic Gray Luvisols.

Three soil series account for the majority of the soils encountered in the study area. These are: Hubalta, O'Chiese, and Judy series (Alberta Soil Survey - unpublished report - T. Macyk surveyor).

Hubalta soils are by far the most common. They are moderately well-drained, orthic gray luvisols developed on till, varying in depth from a few cm to several m. Frequently, they are very cobbly. Topography is usually gently rolling to rolling. Parent materials are olive, olive gray or olive brown in colour.

O'Chiese soils are moderately well-drained Bisequa Gray Luvisols developed on till. They occur in association with Hubalta soils and are developed on the same parent material. They are distinguished from the Hubalta series by a thin brown Bf or Bfj horizon. Stones may be common throughout the profile. Topography is usually undulating to gently



rolling.

Soils of the Judy soil series are found at higher elevations and are not important in the stands studied. These soils are well to moderately well-drained brunisolic gray luvisols developed on extremely gravelly till.

#### E. Clearcutting Operation

"Clearcutting" is here defined as the removal of all trees of "merchantable size" (i.e., greater than 15cm diameter at stump). Trees smaller than this size may or may not be cut. Trees in the 130 year old even-aged lodgepole pine forests of the study area are almost entirely of merchantable size. Aspen poplars (*Populus tremuloides*) are generally not plentiful in the area, and are either left standing or cut to facilitate the extraction of the more valuable pine. Aspen poplar and other dead trees are currently not utilized by North Western Pulp and Power. Some small pine, black or white spruce may survive the clearcutting operation as "advanced regeneration."

The cones on the slash (branches and tops) that remain serve as the most important seed source for the next pine generation. The logging operation includes the placement of bladed block roads and trails within the clearcut block (tract) to facilitate the removal of timber. Tractors are



now used for skidding logs, though prior to 1965, horses were used.

Within a year or two after logging, the cleared block is mechanically scarified by driving over it with a crawler tractor equipped with a scarifier blade. This operation serves a dual purpose:

- 1) A mineral seedbed is exposed for subsequent lodgepole pine regeneration,
- 2) Fire hazard is reduced when the pine boughs are flattened. The Alberta Forest Service does not allow the burning of logging slash due to the unpredictable winds in the area which may carry a fire into the adjoining uncut forest.

An effort is made to lay the blocks out to minimize windfall on their edges, yet take advantage of the wind so as to maximize dispersal from seedtrees in the adjoining forest.

The clearcut blocks are separated by blocks of undisturbed forest which serves in part as a seed source, wind-break, and watershed. The forested blocks adjacent to the clearcuts are scheduled to be cleared about ten years after the initial clearcut area. After this time, most tree regeneration on the initial clearcut from slash and standing tree seed sources is well established. Any additional



establishment would probably result from imported seed. A narrow band of trees is left standing along streams to reduce bank erosion.



#### IV EXPERIMENTAL METHODS - CLEARCUT AREAS

##### A. Stand Selection

Stands were chosen by the following criteria using forest cover maps (1955) and field inspection. The forest cover maps were of the scale 1:16000 (4 in. to 1 mile), and provided by the Forestry Division of North Western Pulp and Power.

- 1) Each stand had to be within what was pure lodgepole pine before clearcutting as designated by the forest cover map, of medium to over stocked density and 16-30m in height.
- 2) The stand had to occur on topography on minimal relief and as level as possible in order to reduce variation between stands due to topographic and edaphic factors.
- 3) Blocks were 3-30 ha in area.
- 4) Five blocks for each of five different years were selected.

##### B. Vegetation Analysis

###### i. Sampling Scheme

A 100 yard master baseline was laid out in the center of the stand area parallel to topographic contours. Three 100-yard subsidiary baselines were placed at  $90^{\circ}$  to the



master line at random points along the master baseline, one per each 100 foot segment (Figure 2). Whether the subsidiary line went to the left or right of the master line was determined by whether the random number was odd or even. If even, the line went to the right, if odd, to the left. Lines were arranged such that in all cases subsidiary lines were located on both sides of the master line. That is to say, even if all three points were even numbers, the third point would be located to the left of the master line. Sampling was thus done in a maximal area of 100 x 200 yards (92 x 184m) in each of 25 stands. Where subsidiary lines were close, some plot overlap occasionally occurred.

Locations of ten quadrats on each subsidiary baseline were determined using random numbers between 1 and 99 such that three quadrats fell within each 100 ft. segment of the line. The tenth quadrat on each line was located at the end of the line farthest from the master baseline. Distances in feet from the baseline for quadrat locations were similarly determined using random numbers between 1 and 9. Quadrat distances from the subsidiary baseline were paced rather than precisely measured. Thirty quadrats were thus located for each clearcut stand. A 1m x 1m quadrat was nested in the corner of a 2m x 2m quadrat at each quadrat location.

Sample size was determined by constructing species-



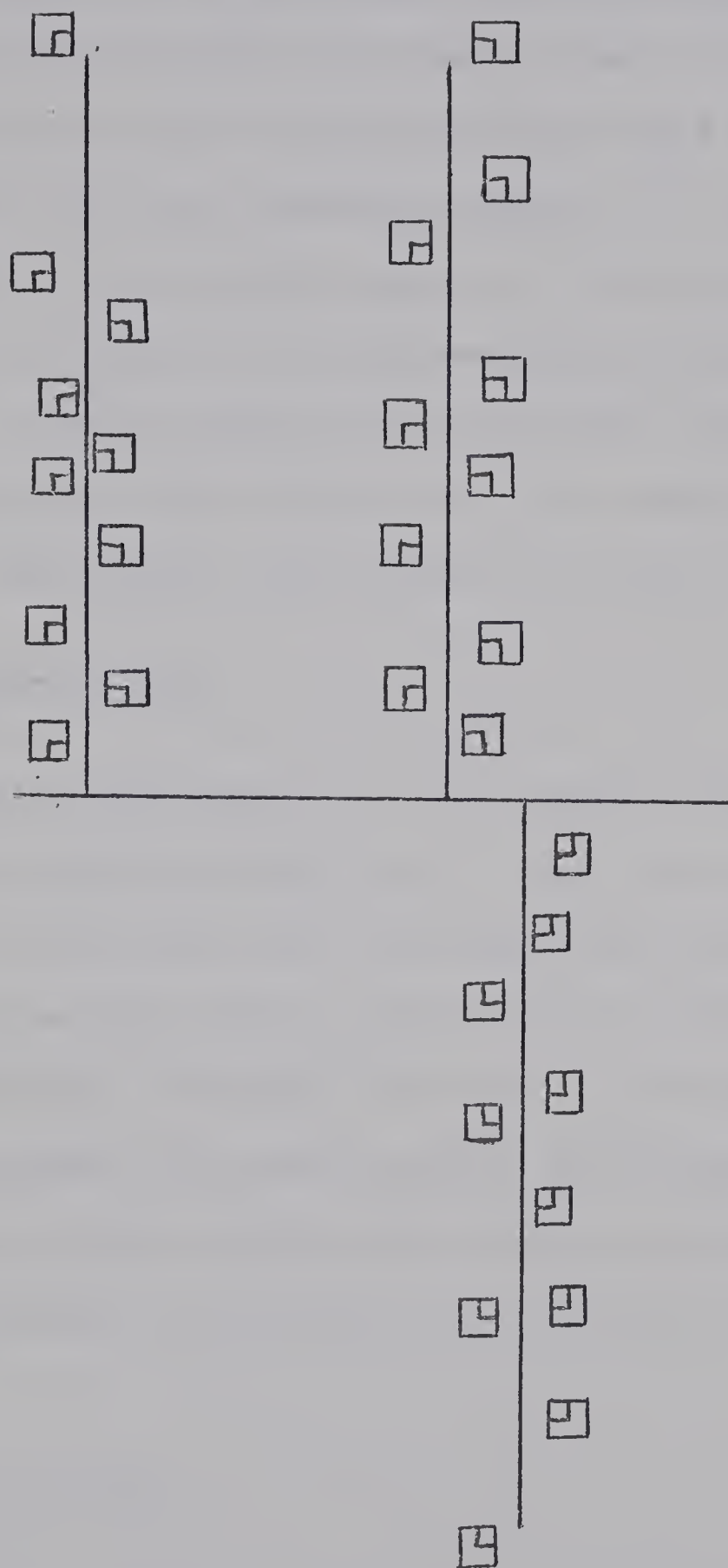


FIGURE 2. Sampling Scheme and Quadrat Layout



area curves in the field for two of what were considered to be the most diverse of the stands selected. These preliminary tests showed that the most species in the stand area were recorded in the first ten quadrats sampled. It was realized though that a low standard error of the mean for species cover was not likely to be achieved only using ten quadrats per stand. Thirty quadrats were decided upon as being maximal in terms of time allotted for the study and field efficiency. This number was adhered to in all stands.

#### ii. Tree Regeneration

Tree regeneration for all species in each stand was tallied by height classes (e.g., Fig. 23) along three 1m wide belts coinciding with the subsidiary baselines. Whether the belt was on the left or right side of the line was determined by whether the point of origin of the subsidiary line on the master line was an even or odd number. If even, the belt was on the right side, if odd, on the left. Each belt transect was divided into six 50-ft. segments.

#### iii. Vegetation Cover

At each quadrat location a 1 x 1m steel quadrat frame was nested in the corner of an imaginary 2 x 2m quadrat. In the 1 x 1m quadrat, cover estimates of total and individual herb, bryophyte and lichen species,



bare soil, logging slash and dead grass were made using a 10 class modified Braun-Blanquet scale (Appendix 2).

Cover estimates of shrubs taller than 46cm were made in the 2m x 2m quadrats. If there was any doubt of a shrub being included in the imaginary 2 x 2m quadrat, the 1 x 1m quadrat was turned over such as to measure 2 meters from the lower corner of the quadrat.

#### C. Microenvironmental Data

Litter depth was measured in each 1 x 1m quadrat together with estimates of relative disturbance and uniformity using 4-point scales (Appendix 1). An estimate of slope, angle and microrelief was made in both 1 x 1m and 2 x 2m quadrats.

#### D. Species List and Stand Description

A species list was made within each 100 x 200 yard stand. Additional species occurring outside the stand area on habitat similar to that sampled were included on this list. Predominant height, phenology (vegetative and reproductive), and dispersion were also noted for each species on the list (Scales in Appendix 2). Unknown species were collected and kept for later determinations. Moss (1959) was the taxonomic authority.

A stand description was made in each sampling area



noting landscape and vegetational features as well as subjective observations on tree regeneration, insect and animal effects and activity, and other environmental characteristics and effects.

#### E. Physiographic and Edaphic Variables

All stands were located between 1030 and 1160m in elevation using a 1:50,000 topographic map. It was believed this method was more accurate than using an altitude barometer due to the rapid changes in barometric pressure that can occur in the area in a short time period.

##### i. Soil Profile Description

One soil pit was dug in each stand. It was located in what was believed to be a representative position, topographic lows and highs being avoided. The soil profile was examined and described noting structure, texture, color and thickness of existing horizons. Samples for subsequent laboratory analysis were taken at the surface, 10 cm, 30 cm, and 60 cm. These depths usually approximated midpoints for the L-H, Ae, Bt, and C horizons respectively. Where diagnostic horizons did not coincide with these depths, additional samples were taken.

Hydrogen ion concentration was determined in the field for all horizons using a Hellige Truog soil reaction



kit. The presence of free lime was determined using a dilute H Cl solution in the field.

An estimate of soil profile variability within the stand was determined by making at least two borings with a small auger at different topographic positions within the stand. Horizon depth, pH, and manual texture were noted and compared to that of the soil pit.

## ii. Field Moisture

Twice during the summer, soil samples were taken at 3 random locations along the master baseline at 10 and 20 cm depth in order to evaluate relative soil moisture status within each stand. The location of the soil-moisture pits coincided with the point of origin of the subsidiary baselines. The gravimetric soil moisture samples were weighed moist in the field and dried to constant weight at 105° C in the lab. Water content was expressed as a percentage of the oven dry weight.

## iii. Physical Properties of the Soil

Texture: each mineral soil sample was mechanically crushed to facilitate passage through a 2mm screen. This fraction was collected for subsequent analysis.

Mechanical analysis was done on the 2mm fraction of



the mineral soils using the revised hydrometer method (Bouyoucos 1951). A New Brunswick Scientific Company reciprocal shaker (model R-7) was used to disperse soil aggregates prior to the mechanical analysis procedure.

Moisture: Field capacity was determined for duplicates of each soil sample using the porous pressure plate apparatus (Soil moisture model 1500). Saturated samples were subjected to a pressure of one-third atmosphere for 24 hours, weighed, oven-dried at  $105^{\circ}\text{C}$  and reweighed. Water content is expressed as a percentage of the oven dry weight of the soil.

Permanent wilting percentage was determined for duplicates of each soil sample using the pressure plate apparatus (Soil moisture model 1600). Saturated samples were subjected to a pressure of 15 atmospheres for 24 hours, weighed, oven-dried at  $105^{\circ}\text{C}$  and re-weighed. "Available" soil water of each sample was obtained by subtracting the mean permanent wilting percentage from the corresponding mean field capacity.

Soil Temperature: Mean stand soil temperature at 20 cm depth was calculated for each of the plot areas using quadrat temperature readings obtained with a Weston dial thermometer. Stands were sampled on 25 days between June 23 and July 22. A correlation was calculated between Edson air, and stand soil temperature. A regression was calculated



relating soil and air temperature so as to enable correction of soil temperatures for differences in air temperature. Analysis of variance was made for corrected and uncorrected soil temperature. Edson temperature data were used rather than hygrothermograph data at camp due to problems encountered with instrument calibration.

Group mean soil temperature was calculated for each set of five stands cleared within a given year. Mean soil temperature was plotted against time in years since clear-cutting. Each point thus represents the mean of 150 soil temperature readings.

#### iv. Chemical Properties of the Soil

Available Nutrients: A soil sample from the surface mineral horizons of each stand was analyzed for concentration of available nitrogen, phosphorous and potassium by the Provincial Agricultural Soil and Feed Testing Laboratory. Results are expressed as parts per million. A subjective estimate of free lime content was obtained for each sample submitted to the lab.

Soil Reaction: Soil reaction (pH) determinations were made by the Agricultural Soil and Feed Testing Lab on the 29 samples submitted.

Soluble Salts: The conductivity (mhos) of each soil



sample was measured by the Soil and Feed Testing Lab to determine concentration of soluble salts.

#### F. Height-Age Determination

Although the age of each clearcut block was known, there remained the possibility that subsequent tree regeneration did not accurately reflect the date of stand origin. Therefore, on each of three stands cleared during 1958-59 and on each of three stands cleared during 1964-65, approximately 20 specimens each of *Pinus contorta* and *Populus tremuloides*, the stand dominants, were cut at ground level, height measured, and a disc sawed from the base of the stem for subsequent age determination and diameter measurement in the lab. Approximately one-half of the sample consisted of the largest individuals found in each species population in the block; the other half was composed of individuals spanning the range of size within the block. In some cases, in order to include larger trees, it was necessary to take specimens from outside the stand area.

#### G. Biomass

On the same 6 stands for which height-age determinations were made, an estimate of above-ground pine and aspen biomass was obtained using a destructive sampling technique. Fifty to 70 trees for each of pine and aspen were cut at



ground level, height and basal diameter recorded, and fresh weight measured using a Hanson spring scale for trees  $>3.6$  kg and a Zebco model 208 fisherman's scale for trees  $\leq 3.6$  kg. Both scales were later calibrated in the laboratory, and field fresh weight measurements corrected accordingly.

Individual trees felled were selected by height so as to obtain a fairly accurate estimation of the weight of an average pine or aspen in each height class, for each of the 6 stands sampled in this manner.

Conversion of fresh weight to dry weight data was accomplished by felling 3 average-sized trees of both pine and aspen and measuring height, total branch and bole weights for each tree. The subsample sections were taken from each tree bole plus a composite subsample of foliage and branches. Fresh weights of these subsamples were determined in the field using an O'Haus triple beam balance. The subsamples were then air-dried in the field and subsequently oven-dried to a constant weight at  $65^{\circ}\text{C}$  in the laboratory. Using dry-fresh weight ratios from the subsamples and weight/height ratios from the larger harvest sample, a dry biomass/ha estimate was obtained using the height and density data from the transect tree regeneration tallies.



## V EXPERIMENTAL METHODS - MATURE LODGEPOLE PINE FORESTS

### A. Stand Selection

One of the major objectives of this study was to describe the original forest communities, to allow comparison with adjacent clearcut blocks and lodgepole pine forests elsewhere. Accordingly 20 undisturbed stands from the same original forest clearcut stands were selected from the forest cover map and sampled in locations adjacent to 20 of the clearcut stands.

### B. Vegetation Analyses

#### i. Sampling Scheme

A 100 yard baseline was located in the stand 50 to 100 meters from the edge of the block in order to minimize the effects of the clearcut block upon the mature forest. Ten quadrats were located along the baseline in the same manner as the placement of the quadrats along the subsidiary baseline in the cutover, with the exception that quadrat distance from the line was in 1 meter paces rather than in feet. A 1 x 1m quadrat was nested in the corner of a 5 x 5m quadrat.

#### ii. Tree Density

All trees with stems over 2.5cm DBH rooted in the 5 x 5m quadrat were counted by species. The diameter



of each tree was recorded. Separate records were made of living and dead standing trees.

All tree reproduction less than 2.5 cm DBH was counted by species, with separate records for living and dead stems, but diameters were not measured.

#### iii. Basal Area

Basal area at 2m above ground was estimated for each tree species at 10 random points along each baseline using a 10X Bitterlich prism recording living and dead trees separately.

#### iv. Tree Canopy Cover

Vertical photographs were taken of the tree canopy from 1 meter above ground at 10 random points along the baseline using a Kodak Instamatic camera. These photographs were subsequently used for laboratory determination of percent canopy cover, employing the method described by Beil (1966).

#### v. Increment Cores

In order to obtain information on stand history and to evaluate tree growth in the stand, five or six trees were bored with a 3.5mm Swedish tree borer. Height and DBH were measured for each tree. These trees



included the two largest (diameter) seen in the stand plus 3 or 4 others deemed typical of the stand.

#### vi. Vegetation Cover

Estimates of herbaceous and bryophyte cover by species were made in the 1 x 1m quadrats as on the clear-cut. Cover estimates were made in the 5 x 5m quadrats for shrub species greater than 46cm (18") tall. The average height of each shrub species was subjectively estimated for each quadrat.

Physical habitat data were recorded as on the clear-cut stands.



## VI RESULTS AND DISCUSSION

### A. Mature Lodgepole Pine Forest

#### i. Tree Stratum

All but one of the 20 mature pine stands studied originated after a fire which devastated the area in 1840. Stand number 12 originated after a fire in 1889. Total living basal area of lodgepole pine averages between 3.6 and 9.7m<sup>2</sup>/ha (90-230 ft<sup>2</sup>/acre). Black spruce comprises 0 to 26% of the basal area of the stands. White spruce is much less frequent and comprises a maximum of 6% of the basal area. Aspen poplar comprises 0 to 51% of the basal area. Occurrences of mature balsam poplar and paper birch were rare. Mature subalpine fir and larch were absent in the stands sampled.

Lodgepole pine is the dominant tree throughout the study area, and does not noticeably change in abundance with an increase in elevation. There is a tendency for aspen poplar to decrease and for subalpine fir and black spruce to increase in abundance in the sampled stands with increasing elevation northward across the study area. Black spruce is also abundant at lower elevations on moist, poorly-drained sites (not sampled). White spruce occurs on moist sites throughout the elevational range studied, often with black



spruce. Mature balsam poplars usually occur at elevations below 1100m and then only in moist depressions or on stream banks. Paper birch is very rare in the study area and appears to be sporadic in occurrence with no apparent altitudinal affinities.

Without fire, lodgepole pine would not likely have remained a dominant feature of the natural forest landscape in the study area. Secondary succession is evident in all forest stands sampled. Pine regeneration is very scarce within all the control stands studied. The few pine seedlings and saplings that do occur are found under openings in the forest canopy created by selective felling of trees for railroad ties and mine timbers many years ago, or under natural canopy openings resulting from windthrow of infirm trees. Thus, the pine forests do not appear able or likely to succeed themselves naturally, and numerous black and white spruce are generally well established by the time mature pines are felled by wind. Young pines were sometimes observed rooted on exposed mineral soil on animal trails within the pine stands.

Ring counts from increment cores taken at breast height on the lodgepole pine forests indicate that black and white spruce are generally ten to thirty years younger than the pine in the stand. It should be recognized here though,



that height growth of both spruce species is much slower than that of pine in the early stages of life.

Black spruce is invading successfully in many stands, often reproducing by layering. Black spruce appears destined to become an important constituent of natural pine forests of fire origin in the Edson region.

Subalpine fir reproduction was evident in many of the mature pine stands. This species did not reach tree stature in any of the stands sampled, nor was it common in other low elevation forests. North of the study area at elevations above 1200m individual firs often reached diameters of over 25cm and heights of 20m. Young subalpine fir trees in the forests of the study area are often of a prostrate rather than erect form due to repeated browsing by ungulates and, in many cases, fir is reproducing vegetatively in the same manner as the black spruce.

Both aspen and balsam poplar and paper birch seem to require sizeable openings in the tree canopy to become successfully established and reproduce. Regeneration of hardwood species in the forests is even more haphazard than that of pine; they do not appear likely to form a significant fraction in the future forest generation. Hypothesizing the ultimate outcome of natural forest succession after fire in these forests is an academic exercise because all the lodge-



pole pine stands sampled will likely be clearcut within the next ten years. Even if they were not logged, it is unlikely that they would reach what would appear to be a black spruce-subalpine fir climax before being ravaged again by fire. The hypothesis of a spruce-fir climax is in accordance with Cormack (1953), Smithers (1961), and Hnatiuk (1969).

## ii. Shrub Stratum

The shrub stratum includes all woody, non-arboreal species greater than 46 cm in height. Green alder (*Alnus crispa*) is the most conspicuous constituent of this stratum. In several stands it forms a dense understory 2½ - 3m tall.

Associated with a dense alder shrub understory is a lush and floristically diverse herb stratum, indicating a moist (and fertile) site.

The willows, prominent in height of individuals, rank second to *Alnus crispa* in this respect, have only local occurrence in the stands sampled. *Salix bebbiana*, the most common species, forms a scattered shrub understory in some pine stands, occurring in the more poorly-drained areas at elevations below 1100m. *Salix* species appear to be scarce above this elevation.

Other shrub species occurring in the study area are



indicative of a moist environment. *Ribes glandulosum* and *R. triste* are common, with scattered occurrences of *R. hirtellum* and *R. lacustre*. *Sorbus scopulina*, the mountain ash, is of scattered occurrence, with some individuals as tall as 3m. The lowbush cranberry, *Viburnum edule* and the bracted honeysuckle *Lonicera involucrata* occur with about the same frequency in the moist pine forests. *Rosa acicularis* is common in many stands. *Rubus strigosus* appears to be restricted to the lush understory of the *Abies* type of pine community. *Amelanchier alnifolia* is very rare in the area. Only two individuals were recorded in stands sampled. *Lonicera dioica*, *Spiraea lucida* and *Shepherdia canadensis* are found primarily in open stands with a history of ground fire or partial cutting. *Shepherdia* appears to prefer well-drained ridges at elevations below 1100m. *Clematis verticellaris* is of sporadic occurrence.

### iii. Herb-Dwarf Shrub Stratum

The herb-dwarf shrub stratum includes all vascular species less than 46 cm (18") in height. This stratum forms a prominent and distinctive part of the mature lodgepole pine forest community.

A striking feature of most stands is the fairly uniform cover of abundant *Ledum groenlandicum* and *Vaccinium myrtilloides*. These two ericads have an average height of



about 30 cm. Commonly associated with these species are *Vaccinium vitis-idaea*, *Linnaea borealis*, *Cornus canadensis*, and *Petasites palmatus*.

*Vaccinium caespitosum*, though present in many stands, is usually not abundant and is not as consistent in occurrence as are the above species.

The pine forests sampled possessed from 17 to 52 species in the herb-dwarf shrub stratum. Stands of low species diversity occurred at higher altitudes, 1100m, in the north part of the study area. These stands were characteristically quite dense with black spruce being abundant and crown canopy very dense. Species most common in more open low-elevation stands, included *Pyrola asarifolia*, *Maianthemum canadense* and *Rubus pubescens*. In two of the higher elevation pine stands with the sparse understory, *Rubus pedatus* was found. This species is common in the high elevation pine stands above 1100m on the plateaus or table lands, and did not occur in any of the other stands.

The abundance of two grass species, *Elymus innovatus* and *Calamagrostis canadensis* varies and is correlated with the moisture regime of a stand. *Elymus* is generally more abundant within the forest than is bluejoint, and indicates a dry site. Bluejoint conversely reflects a moist condition.

Other herbs commonly found in the mature lodgepole



pine forests of the Edson area include *Aster ciliolatus*, *Mitella nuda*, *Lathyrus ochroleucus*, *Equisetum arvense* and *Galium boreale*.

#### iv. Bryophyte Stratum

Typical of the mature lodgepole pine forest of the study area is a nearly continuous moss cover. The majority of the moss cover is composed of *Hylocomium splendens*, *Pleurozium schreberi*, *Ptilium cristacastrensis*, *Polytrichum commune* and *Aulacomium palustre*.

Lichens are not abundant on the floor of the lodgepole pine forests. *Peltigera* spp. are the most abundant lichens, particularly in dry sites.

### B. Vegetation of the Clearcut Blocks

#### i. Systematic Consideration

A total of 100 species, 70 genera, and 31 families were reported in the vascular flora within quadrats of the 25 stands sampled. The most important family in terms of number of species was Gramineae with 13, followed by Rosaceae and Compositae which had 9 and 8 species respectively.

#### a. Presence

Presence values were determined for all species by expressing the number of stands of occurrence as



a percentage of the total number of stands.

The distribution of the sampled flora in the five presence classes (1-20%, 21-40%, etc.) suggests that the initial stages of secondary succession after clearcutting of lodgepole pine are floristically quite uniform (Fig. 3). This uniformity is shown in the fact that 26% of the vascular flora occurred in more than 60% of the stands. About one-half of the species occurred sporadically, i.e., in less than 20% of the stands sampled.

b. Frequency (per 1 x 1m plot)

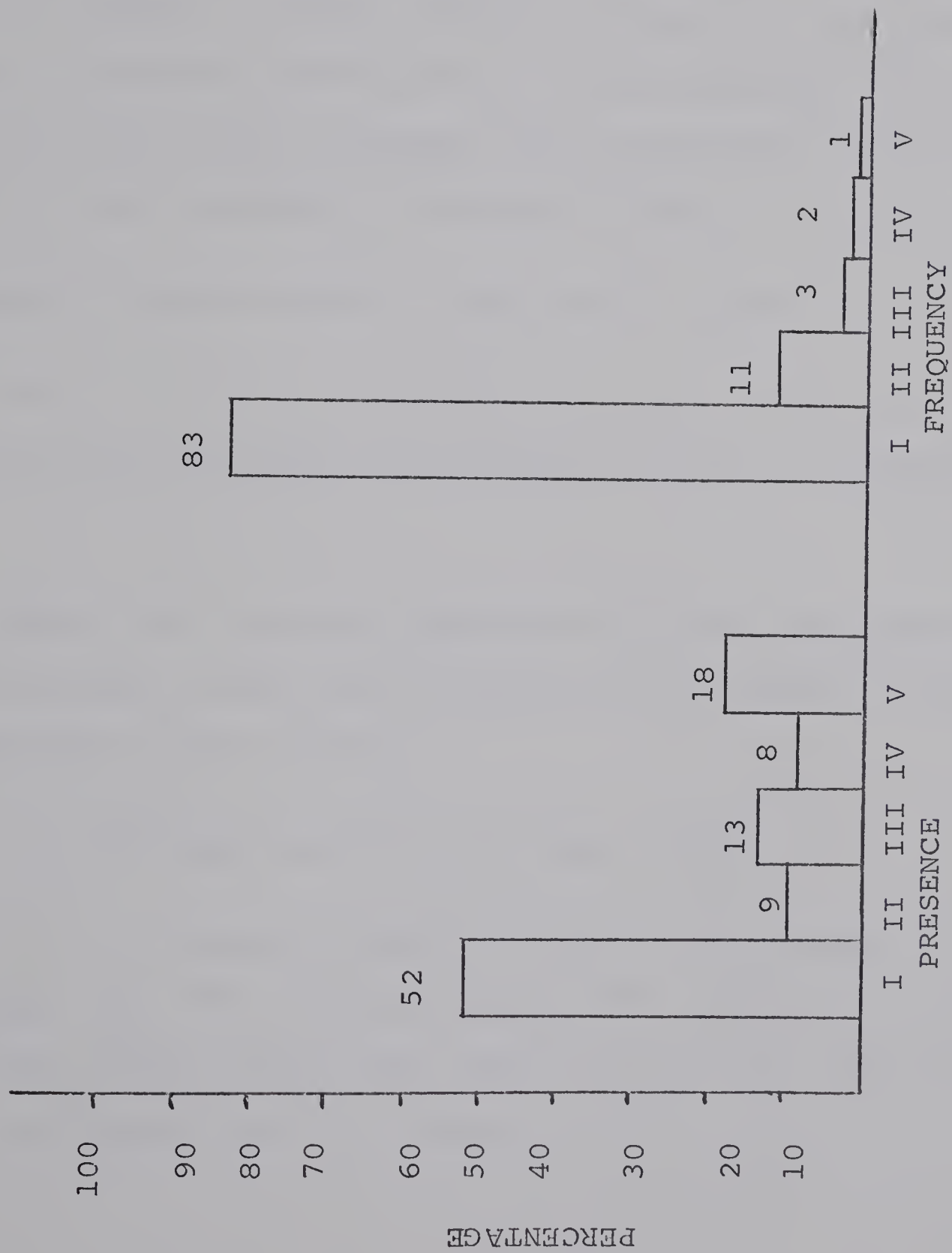
Frequency values were obtained for each species by expressing the number of quadrats of occurrence as a percentage of the total number of quadrats (750) in the 25 stands.

The frequency class distribution (Fig. 3) illustrates that although the stands are fairly uniform on a presence basis, only a small number of species (6) occurred in a large percentage of the plots (i.e., 40% frequency). The six species listed in order of decreasing frequency are: *Epilobium angustifolium* (89%), *Cornus canadensis* (67%), *Elymus innovatus* (59%), *Rosa acicularis* (56%), *Linnaea borealis* (42%) and *Petasites palmatus* (41%).

The species listed above have in common a very ef-

FIGURE 3. Presence and frequency class distributions of the vascular strata on the cleared stands

In each diagram the bars represent progressively higher percentage classes from left to right (1-20; 21-40; 41-60; 61-80; 81-100). The height of each bar represents the percentage of species which occurred in that class and the number of species is given at the top of each bar.





fective vegetative mode of reproduction, by underground roots or rhizomes. With the exception of *Epilobium angustifolium* and *Rosa acicularis*, these six species are also abundant in most of the mature lodgepole pine forests of the study area. *Epilobium*, *Elymus* and *Rosa* increase in abundance following clearcutting. Fireweed is mostly an invader by airborne seed as opposed to *Elymus* and *Rosa* which increase in abundance from material already present. The species of high quadrat frequency make significant contributions in other respects as discussed later.

## ii. Presence Classification of the Vascular Strata

In the following discussion, presence values of species will be indicated parenthetically after the species name.

There are 7 species represented in the tree regeneration, 11 species in the shrub stratum and 82 species in the herb and dwarf shrub stratum.

### a. Tree Regeneration (over 46cm tall)

Listed in order of decreasing presence of individuals over 46cm tall are aspen (96), pine (84), balsam poplar (64), black spruce (16), white spruce (12), subalpine fir (4), and paper birch (4) (Table 3).



TABLE 2. Presence Class Distribution of Vascular Species by Strata Within the Clearcut Stands

Class	Percentage	Number of Species			
		Trees	Shrubs	Herbs	Total
I	0-20	2	5	45	52
II	21-40	0	5	4	9
III	41-60	0	0	13	13
IV	61-80	0	0	8	8
V	81-100	5	1	12	18
<hr/>					
Total		7	11	82	100

TABLE 3. Presence Classification of Tree Regeneration on the Clearcut Stands

Species	Presence (%)	Mean Absolute Cover (%)
<i>Pinus contorta</i>	100	3.00
<i>Populus tremuloides</i>	100	3.09
<i>Populus balsamifera</i>	100	0.20
<i>Picea mariana</i>	92	0.06
<i>Picea glauca</i>	92	0.06
<i>Abies lasiocarpa</i>	16	0.00
<i>Betula papyrifera</i>	16	0.25
<hr/>		
Total		6.60



When individuals under 46 cm tall are included, the presence figures are somewhat different. Three tree species had a presence of 100%. Listed in order of decreasing mean stand stem density they are pine, aspen, and balsam poplar. Black and white spruce (92), subalpine fir (16) and paper birch (16) constituted the remainder of the tree species represented in the study area (Table 3), with fir and birch rarely present. Both spruce species are grouped here because of the difficulty of determining the identity of very small individuals. The relationship of the different species of tree regeneration is discussed in more detail in later sections of this thesis.

b. Shrub Stratum (over 46 cm tall)

Of the 11 shrub species, *Rosa* (88) was by far the most common. On the basis of presence alone, other important shrubs are *Shepherdia canadensis* (40), *Viburnum edule* (36), *Lonicera involucrata* (28), *Alnus crispa* (28), and *Salix bebbiana* (28) (Table 4). There was a marked lack of true shrub vegetation in the cutover blocks of the study area, in contrast to the dense shrub growth following logging in west coastal North America (Isaac 1943, Yerkes 1960).

c. Herb Dwarf Shrub Stratum

Of the 82 species occurring in the herb-















TABLE 4. Cont'd.

Block No. Stand No.	Cut 1958-59										Cut 1960-61										Cut 1961-62										Cut 1963-64										Cut 1964-65										Presence (%)
	2 1	5 2	6 3	7 4	9 5	1N 6	2N 7	8N 8	11 9	12 10	10N 11	22 12	28 13	32 14	9N 15	60 16	68 17	114 18	116 19	121 20	70 21	102 22	103 23	122 24	123 25																										
<i>Populus tremuloides</i>	+	•	1	1	+	+	+	1	1	1	•	+	+	+	+	+	+	+	•	+	+	+	1	+	+	+	88																								
<i>Fragaria virginiana</i>	+	1	+	+	2	•	+	2	+	+	+	+	+	+	+	2	1	1	•	1	4	+	6	•	•	+	88																								
<i>Carex aenea</i>	+	+	+	+	+	+	•	•	1	1	+	+	+	•	+	+	1	1	+	+	+	+	1	+	+	+	88																								
<i>Viola adunca</i>	+	+	•	+	+	+	+	+	+	•	+	•	+	+	+	+	+	+	•	+	+	+	+	+	+	+	84																								
<i>Mitella nuda</i>	+	+	+	•	•	•	+	+	+	•	+	+	+	+	+	+	+	+	+	+	+	+	+	+	•	•	80																								
<i>Viburnum edule</i>	+	+	1	+	+	•	•	+	+	+	•	1	1	•	+	+	+	+	1	•	+	1	+	+	+	+	80																								
<i>Achillea millefolium</i>	+	•	•	+	+	•	1	+	+	+	+	+	•	1	+	+	+	•	•	+	+	+	+	+	+	+	76																								
<i>Picea mariana</i> and <i>P. glauca</i>	+	+	+	+	7	•	•	•	3	•	+	•	+	7	•	+	+	3	3	13	•	7	•	10	3	+	72																								
<i>Populus balsamifera</i>	+	•	+	+	•	+	•	•	+	•	+	+	+	•	+	1	+	+	•	+	+	+	•	1	+	+	68																								
<i>Equisetum arvense</i> and <i>E. sylvaticum</i>	+	+	•	•	•	•	+	•	1	+	+	•	+	+	+	+	+	•	4	1	•	•	+	1	•	•	68																								
<i>Vaccinium caespitosum</i>	1	1	•	1	2	2	•	2	+	1	+	•	1	5	•	•	•	5	•	+	2	1	•	1	+	+	68																								
<i>Lathyrus ochroleucus</i>	1	+	1	1	1	+	+	1	•	•	•	+	•	•	•	+	+	•	•	•	+	+	•	+	•	•	60																								



















TABLE 4. Cont'd.

Block No. Stand No.	Cut 1958-59										Cut 1960-61						Cut 1961-62										Cut 1963-64										Cut 1964-65										Presence (%)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
	2					5					6					7					9					1N			2N			8N			11			12			10N			22				28			32			9N			60			68			114			116			121			70			102			103			122			123																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
	1	2	3	4	5	1	2	3	4	5	6	7	8	9	10	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	21	22	23	24	25																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
<i>Smilacina stellata</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.</

\* - individuals taller than 46 cm; a - percent cover from modified Braun-Blanquet scale estimates in quadrats; b - frequency per 2x2m quadrat for tree regeneration and shrubs, 1 x 1 m for all other species; c - species present in quadrats the remaining species and the stands in which they occurred are included in Appendix 4; "+" - present in stand but cover <0.5%.



TABLE 5. PERCENT COVER AND QUADRAT FREQUENCY OF MOSS AND LICHEN SPECIES

WITHIN THE CLEARCUT STANDS

		Cut 1958-59					Cut 1960-61					Cut 1961-62				
Block No.	Stand No.	2	5	6	7	9	1N	2N	8N	11	12	10N	22	28	32	9N
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
MOSSES:																
<i>Polytrichum commune</i>		1	1	4	4	5	7	4	1	9	11	4	3	8	7	2
		27	17	47	53	47	67	53	30	83	60	47	20	70	50	20
<i>Ptilium crista-castrensis</i>		.	+	1	1	+	+	1	+	+	5	1	.	1	+	1
		.	7	17	20	3	7	13	3	10	40	13	.	43	10	7
<i>Pleurozium shreberi</i>		.	4	3	3	8	2	11	3	1	11	1	1	3	3	.
		.	70	43	63	83	50	77	50	17	67	10	23	63	67	.
<i>Aulacomnium palustre</i>		+	+	.	2	+	1	2	1	+	2	1	.	+	+	+
		13	10	.	37	17	43	43	20	13	23	27	.	23	23	7
<i>Hylocomium splendens</i>		12	3	.	.	+	1	.	5	7	.	5	3	1	1	12
		87	40	.	.	3	37	.	50	50	.	43	57	17	13	93
<i>Ceratodon purpureus</i>		2	+	.	2	4	1	1	1	1	1	2	.	+	.	+
		30	13	.	27	40	40	13	33	27	3	10	.	27	.	10
<i>Mnium</i> spp.		.	+	.	.	.	.	.	.	+	.	.	+	.	.	+
		.	3	.	.	.	.	.	.	3	.	.	13	.	.	3
Other Mosses		+	+	.	.	.	.	+	.	.	1	+	+	.	.	+
LICHENS:																
<i>Peltigera</i> spp.		1	+	+	2	3	1	+	+	+	.	+	.	+	+	+
		30	3	13	37	40	30	13	17	10	.	7	.	3	10	3
Other lichens		.	.	.	1	1	+	.	.	.	.	.	+	.	.	.
		.	.	.	20	13	7	.	.	.	.	.	.	.	.	.



TABLE 5. Cont'd.

	Cut 1963-64										Cut 1964-65										Presence (%)
	60	68	114	116	121	71	102	103	122	123	21	22	23	24	25	26	27	28	29	30	
60 68 114 116 121	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	
MOSSES:																					
<i>Polytrichum commune</i>	3	13	1	2	4	4	6	5	3	3	4	70	50	50	53						100
	53	70	43	43	57	47	70	50	50	53	47	70	50	50	53						
<i>Ptilium crista castrensis</i>	.	1	+	1	+	+	1	+	1	.	+	1	+	1	.						84
	.	7	3	10	27	3	30	3	17	.	3	30	3	17	.						
<i>Pleurozium shreberi</i>	.	5	1	.	+	1	2	5	+	+	1	2	5	+	+						84
	.	43	50	.	17	43	47	40	17	17	43	47	40	17	17						
<i>Aulacomnium palustre</i>	+	3	.	+	4	+	+	.	+	.	+	+	.	+	.						80
	3	53	.	3	23	27	17	.	7	.	27	17	.	7	.						
<i>Hylacomium splendens</i>	3	+	7	.	+	1	2	.	+	1	1	2	.	+	1						76
	37	10	63	.	20	37	40	.	7	20	37	40	.	7	20						
<i>Ceratodon purpureus</i>	.	1	+	.	+	1	+	.	1	+	1	+	.	1	+						76
	.	13	17	.	10	50	20	.	23	13	50	20	.	23	13						
<i>Mnium</i> spp.	.	.	.	+	.	.	.	+	.	.	.	.	+	.	.						24
Other Mosses	.	.	.	3	.	.	.	3	.	.	.	.	3	.	.						44
	+	+	.	+	.	.	.	1	.	.	.	.	1	.	.						
	10	7	.	7	.	.	.	17	.	.	.	.	17	.	.						
LICHENS:																					
<i>Peltigera</i> spp.	.	+	.	.	.	+	+	+	.	+	+	+	+	.	+						72
	.	7	.	.	.	13	7	7	.	3	13	7	7	.	3						
Other Lichens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.						16
	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.						



dwarf shrub stratum, 37 have a presence of greater than 20% (Table 4). Eight of these species had a presence of 100% and 7 more had presence values above 80%. Most of these 15 species also occur in the mature uncut pine forest. Species with a stand presence of over 80% on the cleared areas which are usually sporadic in occurrence or absent in the mature pine forest are *Epilobium angustifolium*, *Calamagrostis canadensis* and *Fragaria virginiana*. These species are capable of a rapid increase in frequency and cover after clearcutting of the tree stratum.

Approximately 80% of the vascular flora of the cleared blocks are species commonly found in the mature lodgepole pine forest adjacent to the clearcut blocks.

Invaders of the highest presence are *Epilobium angustifolium* (100), *Poa compressa* (60), *Phleum pratense* (56), *Agrostis scabra* (48), *Taraxacum officinale* (44), *Poa pratensis* (36) and *Trifolium hybridum* (36). All other invaders have presence values of 20% or less (Table 4). Many of the species invading the disturbed habitat may have been introduced in feed given to horses which were used for skidding logs. Though no longer used in the logging operation, horses were common during the period when all stands studied were cleared. Fireweed and the light-seeded composites are dispersed readily by the wind. Birds and mammals no doubt also served as dispersal mechanisms for some of the introduced plants.

FIGURE 4. Lodgepole pine cover from 5-12 years after clear-cutting

Means  $\pm$  standard errors for each year are given.

n = 5

FIGURE 5. Aspen cover from 5-12 years after clearcutting

Means  $\pm$  standard errors for each year are given.

n = 5

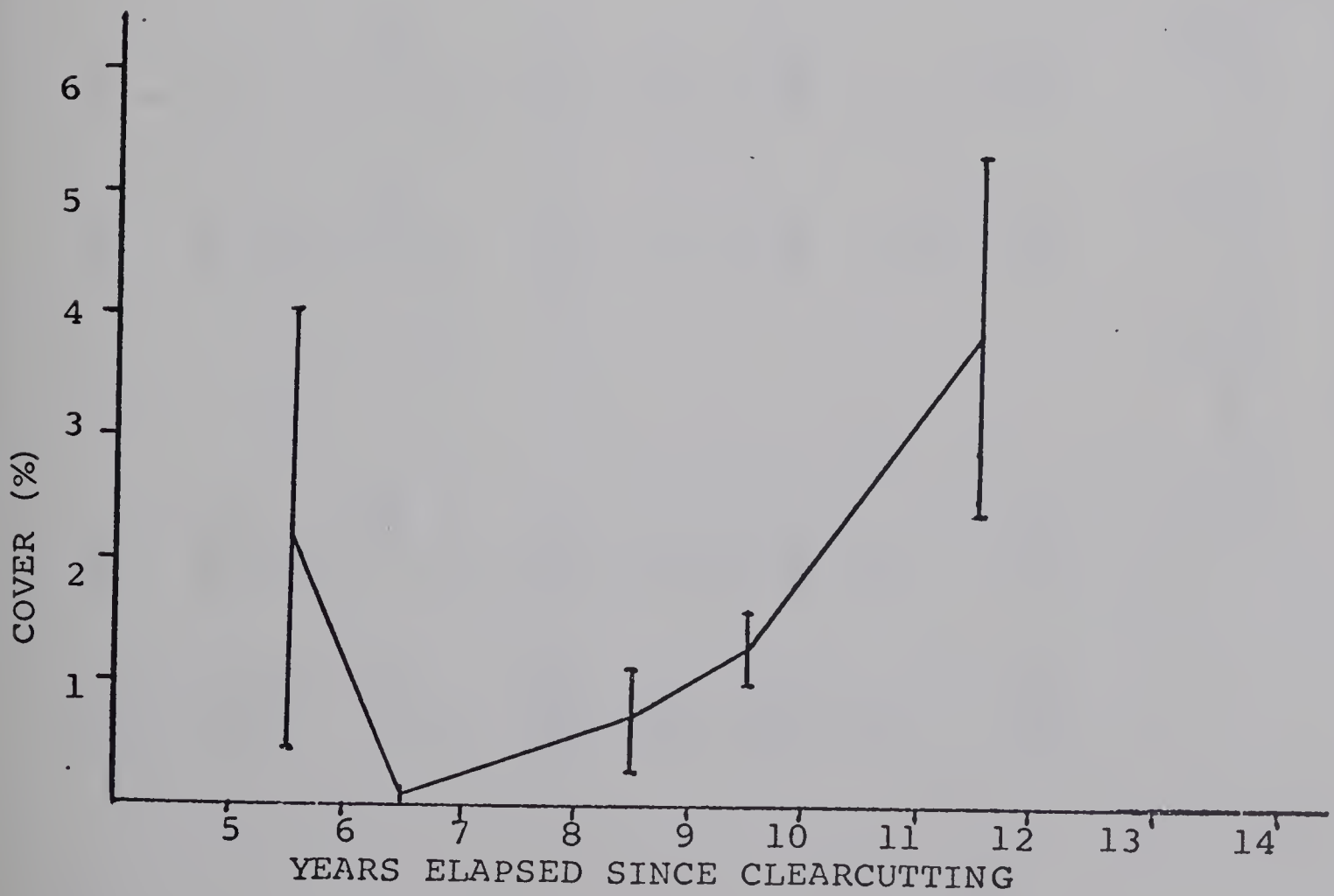
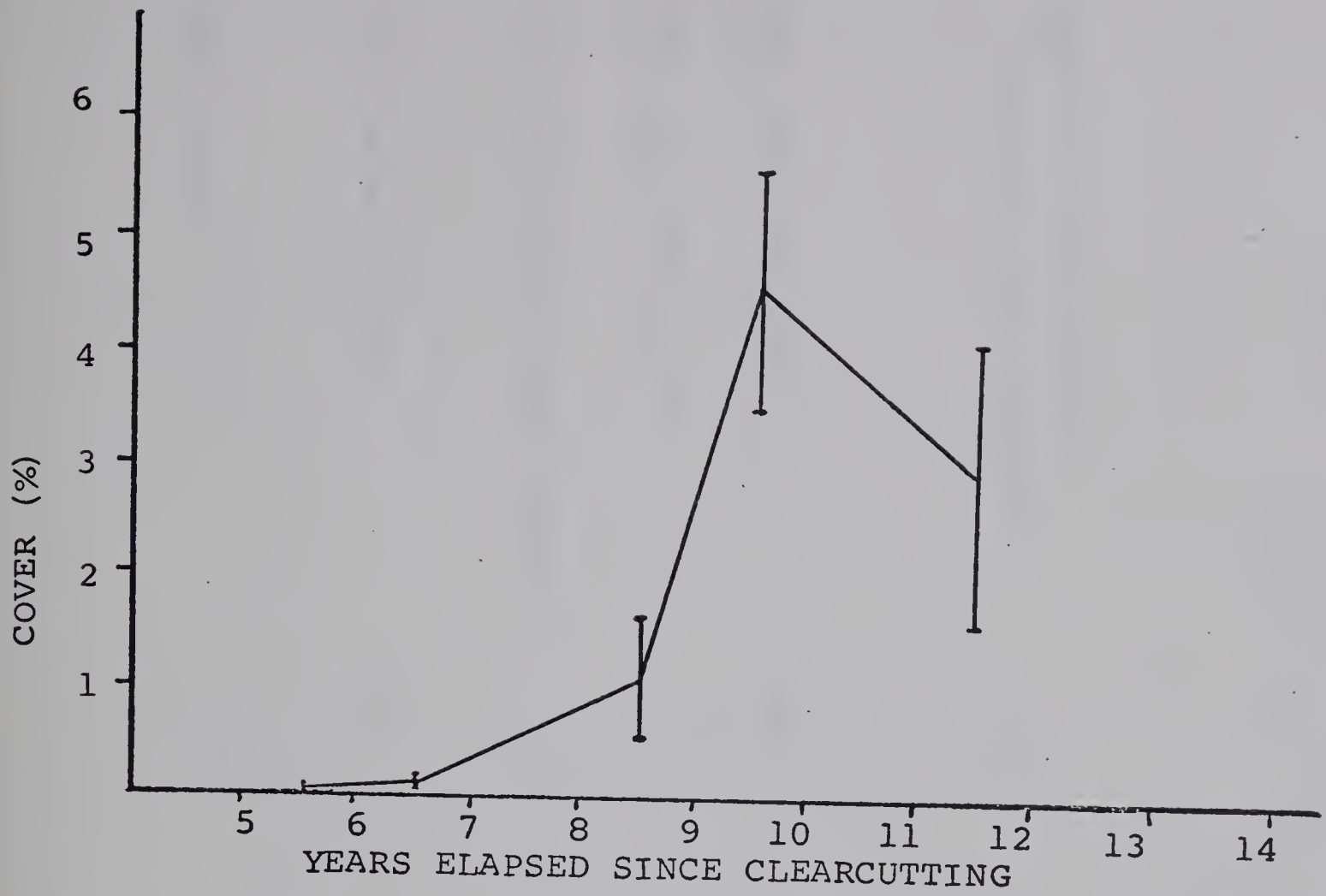




TABLE 6. RESULTS OF DUNCAN'S MULTIPLE RANGE TEST FOR  
SEVERAL STAND ATTRIBUTES

	Years Elapsed Since Clearcutting						
	12	11	10	9	8	7	6
A. Vegetation Attributes							
Lodgepole pine cover**	2.89 a <sup>+</sup> b		4.57 a	1.14 b		0.11 c	0.03 c
Dead pine density**	270 a		138 a	14 b		36 b	65 a
Dead aspen density**	12 a		4 a	4 a		1 b	1 b
<i>Vaccinium vitis-idaea</i> cover**	1.47 a		0.73 a	0.38 b		0.50 a	0.38 b
Total moss cover*	11.9 a b		18.0 a	12.4 a b		10.1 a b	8.1 b
Total lichen cover**	1.58 a		0.40 a	0.08 b		0.04 b	0.10 b



# B. Physical Attributes

	12	11	10	9	8	7	6	5
Stand disturbance**	2.94		2.78	2.58		2.92	3.02	
	a		b			a	a	
	b		c	c		b		
Bare duff cover*	4.42		9.18	16.06		15.96	12.66	
				a		a	a	
	b		b			b	b	
Soil Temperature @ 20cm.**	48.8		47.1	44.3		45.9	45.0	
	a		a	b		a	b	
			b	b		b	b	

\* Differences among years significant at 10% confidence level

\*\* Differences among years significant at 5% confidence level

\*\*\* Differences among years significant at 1% confidence level

+ Means underscored by some letter are not significantly different from each other



### iii. Cover of Vascular Species and Strata

#### a. Tree regeneration

The average cover of tree regeneration was 6.6% and varied from 4% to 12%. Lodgepole pine was the only species which yielded significant differences in cover among years when tested by analysis of variance. The results of Duncan's Multiple Range test on pine cover are shown in Table 6.

Lodgepole pine cover shows a tendency to increase with time after clearcutting (Fig. 4). An apparent tendency for aspen cover to increase is obscured by the great variation in aspen cover among stands cleared during 1964-65 (Fig. 5). The average cover values of pine and aspen for all cutover stands were nearly equal (3.0 and 3.1% respectively). The relationship of pine and aspen is discussed on pages 66, 74, 83 and 107.

#### b. Shrub stratum (over 46 cm tall)

The average shrub cover of the clearcut stands was only 1.1%. *Rosa acicularis* (0.6%) was most important, accounting for over one-half of the shrub cover (Table 4). All shrubs present on the clearcut blocks were also found in the uncut pine forest. No significant differences in cover among years were evident for any of the shrub



species when tested by analysis of variance.

c. Herb-Dwarf Shrub Stratum (over 46cm tall)

The mean estimated cover of herbs and dwarf shrubs in the clearcut stands was 49.8%. The herb-dwarf shrub stratum thus accounts for the greater part of the total vascular cover. The distribution of plant cover within this stratum closely resembles the presence distribution. Only 10 species had a mean cover of greater than 1%. In order of decreasing cover they are *Epilobium angustifolium* (10.2), *Elymus innovatus* (7.8), *Calamagrostis canadensis* (3.8), *Vaccinium myrtilloides* (3.4), *Cornus canadensis* (2.3), *Ledum groenlandicum* (2.1), *Petasites palmatus* (1.8), *Vaccinium caespitosium* (1.8), *Rubus pubescens* (1.6), and *Linnaea borealis* (1.1). Together, they compose 35.9% cover, over half the total mean cover. The above species with the exception of *Epilobium angustifolium* are often abundant in the mature uncut pine stands of the area. The cover distribution among the stands of many of the species is discussed in the ordination section on page 58 .

Most species in the herb-dwarf shrub stratum do not exhibit an increase or decrease in cover in the stands between 6 and 12 years after logging. Cover values of the species which showed apparent changes with time after logging were analyzed using analysis of variance. Only *Vaccinium vitis-*

FIGURE 6. *Vaccinium vitis-idaea* cover from 5-12 years after clearcutting

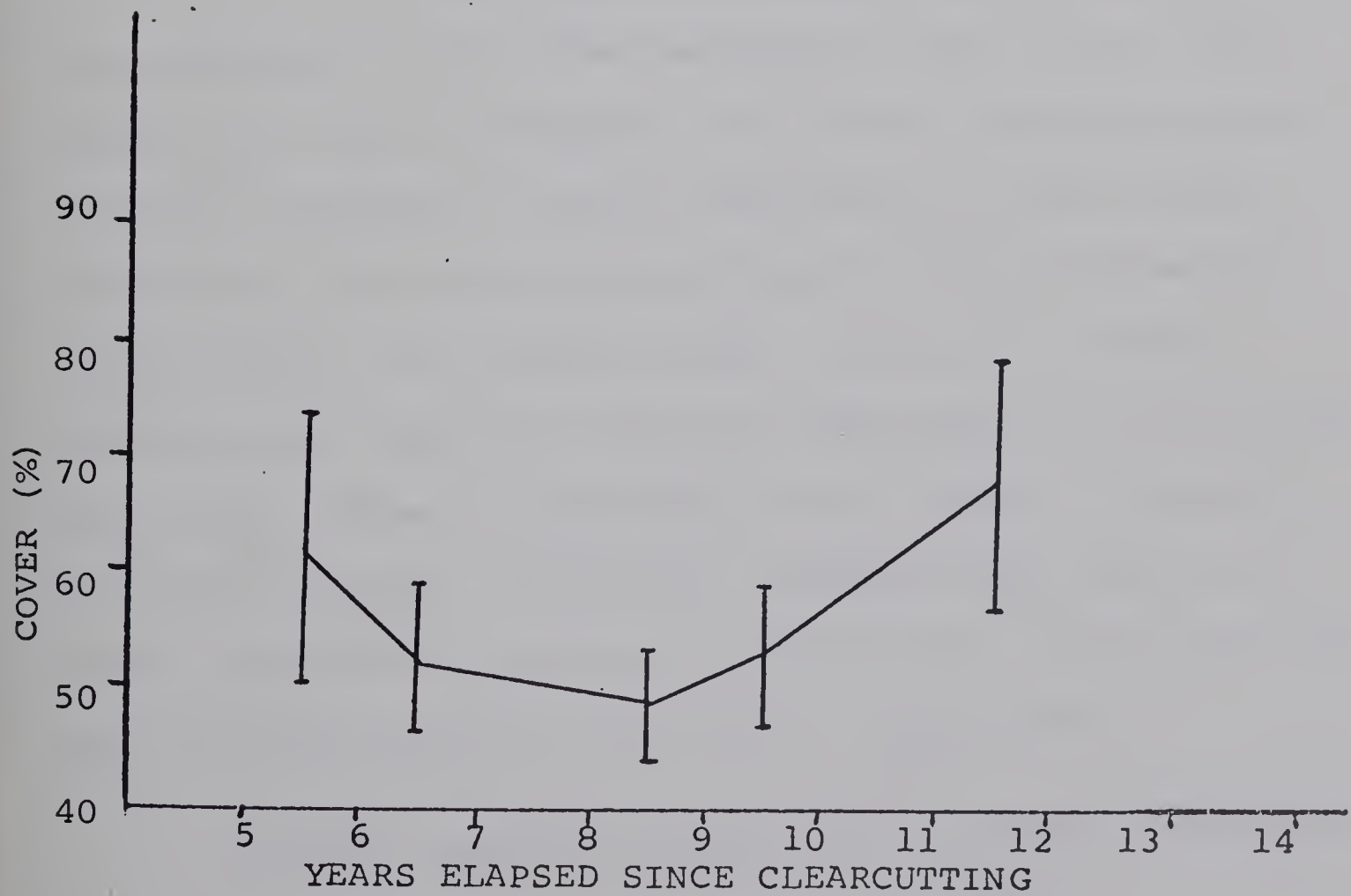
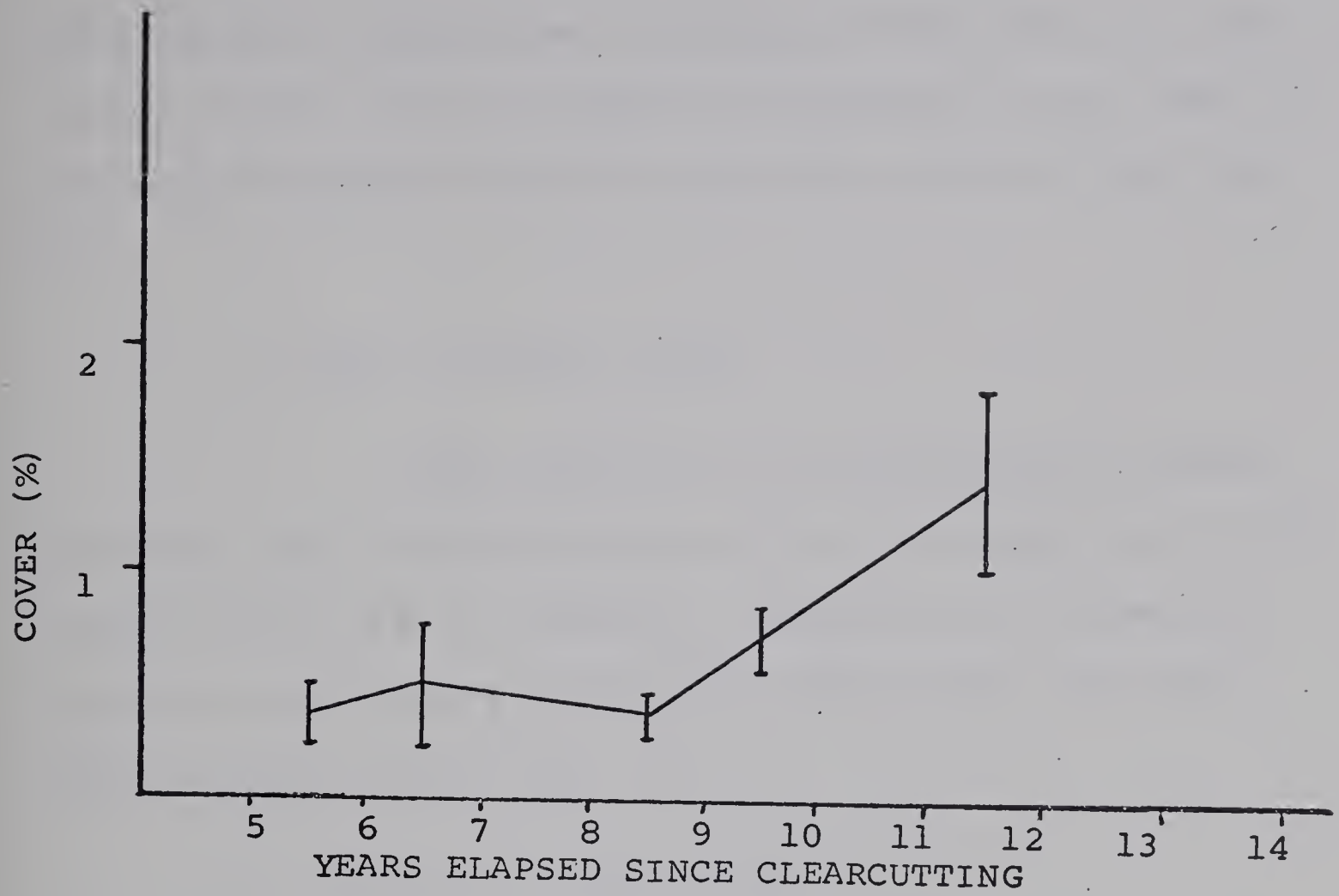
Means  $\pm$  standard errors for each year are given.

n = 5

FIGURE 7. Total vascular plant cover from 5-12 years after clearcutting

Means  $\pm$  standard errors for each year are given.

n = 5





*idaea* showed a significant difference among years (5% confidence level), with an apparent increase in cover that is most rapid between 8 and 12 years after clearcutting (Fig. 6).

d. Total vascular cover

Mean cover of all vascular plant species including tree regeneration was 57.5% and ranged from 38.6% (stand 24) to 101.5% (stand 5). Analysis of variance revealed no significant differences among years for total vascular plant cover (Fig. 7).

e. Vitality and phenology

The dominant species on the cleared blocks are predominantly the same as those of the mature uncut forest, but show differences in vitality and phenological condition compared to their counterparts in the forest. In general, where the species occurs both in the mature forest and on the cleared blocks, vegetative growth, flowering and fruiting occurs on the plants of the cleared area before those in the shade of the forest. Examples include *Shepherdia canadensis*, *Calamagrostis canadensis*, *Elymus innovatus*, *Epilobium angustifolium*, *Ledum groenlandicum*, *Vaccinium myrtilloides* and *V. caespitosum*.

Several species, however, show distinct preferences

FIGURE 8. Total moss cover from 5-12 years after clearcutting

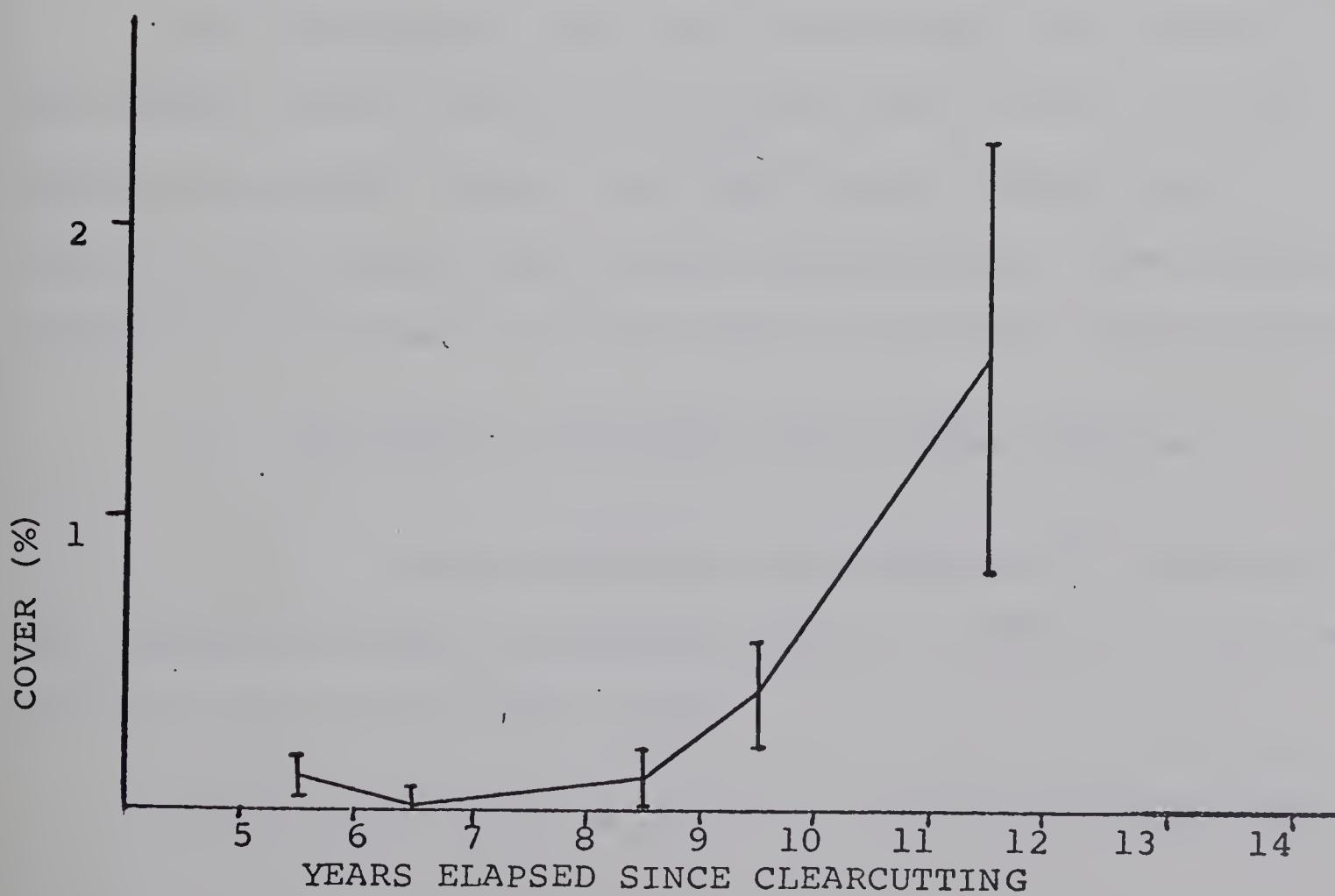
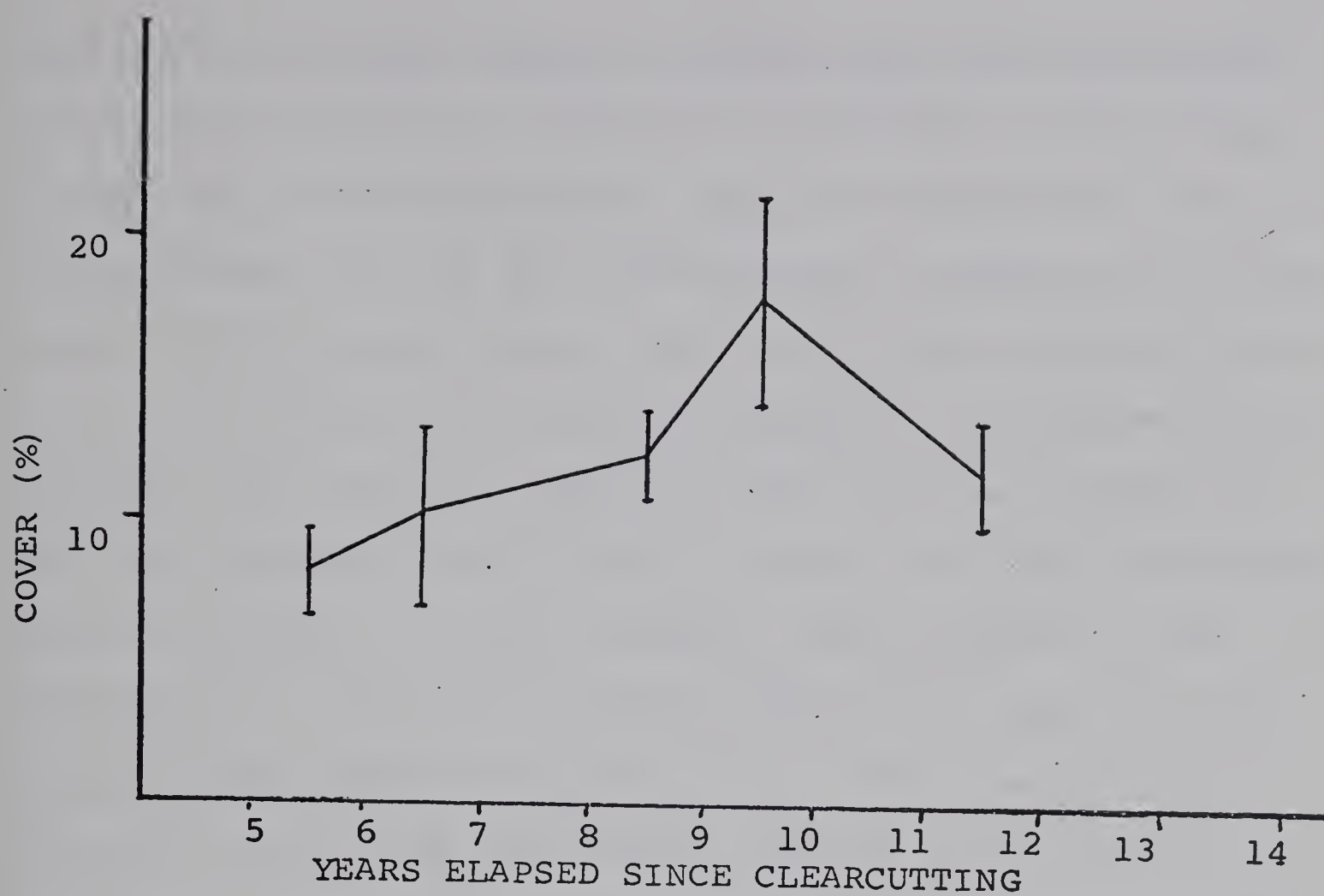
Means  $\pm$  standard errors for each year are given.

n = 5

FIGURE 9. Total lichen cover from 5-12 years after clearcutting

Means  $\pm$  standard error for each year are given.

n = 5





for the forest with respect to flower and fruit production. *Cornus canadensis* is a successful colonizer on the cleared blocks due to its rhizomatous type of reproduction, but it rarely forms fruit on the cleared areas as opposed to *Cornus* plants in the mature forest which often form abundant fruit. *Vaccinium vitis-idaea*, while increasing in abundance on the cleared areas (Fig. 6), does not form fruit as readily as the same species in the forest, showing the shade preference of that species. *Calypso bulbosa*, other members of the Orchidaceae, *Geocaulon lividum*, and *Mitella nuda* are frequent in the mature forest but, very rarely seen on the clearcut areas; they seem better adapted to the cooler, more shady and more humid environment of the forest floor.

Of the species mentioned above which occur both in the mature forest and on the cleared areas, most are more robust, generally taller, and have larger darker green leaves in the forest than on the cleared area. The grasses *Elymus innovatus* and *Calamagrostis canadensis* are exceptions.

#### iv. Terrestrial Bryophyte and Lichen Stratum

Cover estimates and presence for species of the bryophyte-lichen stratum are given in Table 6. The mean cover of the stratum was 12.5%.

Mean moss cover was 12.1% on the cleared blocks as



opposed to a nearly complete coverage in the mature forest. Analysis of variance revealed significant differences between years at the 10% confidence level only. Moss cover shows a tendency to increase with time after clearcutting (Fig. 8).

A rapid disintegration of the feather moss carpet occurs in the first 1-2 years following the clearcut, after which the slow recovery begins. *Polytrichum commune* (4.5), *Pleurozium schreberi* (3.2) and *Hylocomium splendens* (2.6) are the most important moss species with respect to cover (in brackets) and presence (Table 6). *Polytrichum juniperinum* was found to be a large-scale invader in succession after scarification in a boreal Ontario mixedwood (Sutton 1964).

Lichens, with a mean cover of only 0.44%, are much less important than mosses in this respect. *Peltigera* spp of which *P. aphthosa* is most abundant, make up the greater portion (0.4%) of the lichen cover, *Cladonia* spp. comprise most of the remaining 0.08%.

The principal substrate for the lichens is the bare duff, i.e., the dead moss layer of the previous forest. Crustose forms of lichen on logging slash do not contribute a significant amount to lichen cover.

Analysis of variance of total lichen cover reveals significant differences among years at the 5% confidence level. Lichen cover tends to increase over the time span



studied with increases most pronounced between 8 and 12 years after logging (Fig. 9).

### C. Ordination of Clearcut Stands

#### i. Introduction

It now seems appropriate to consider the relations of the clearcut stands to each other. Ordination, a continuous classification method (Bray and Curtis 1957), has the advantage of accurately describing both vegetational and environmental gradients as well as discrete or discontinuous types of variation. Spatial relationships between stands on an ordination are directly proportional to the degree of similarity between the stands.

#### ii. Computation and Construction

Mean absolute plant cover values were used as the basis for the calculation of coefficients of similarity between stands (Bray and Curtis 1957) as follows:

$$\text{Coefficient of similarity} = 2W/A+B$$

where A is the sum of the cover values for plants in one stand,

B is the sum of the corresponding values for a second stand,

W is the sum of the lesser values for those species common to both stands,

$$\text{Coefficient of dissimilarity} = 1 - \text{coefficient of similarity.}$$



Following the ordination construction procedure of Bray and Curtis (1957), the first X axis reference stand (No. 19), was chosen as the one most dissimilar to all other stands. Dissimilarity indices were calculated for this stand with all others. Stand number 23 was most dissimilar to the first X axis stand and used as the other X axis reference stand. The remaining 23 stands were plotted on X according to their dissimilarity with the end stands, by arc projection (Bray and Curtis 1957). The first end stand on the Y axis (No. 21) was most dissimilar to both end stands of the Y axis and situated near the center of the X axis. The second end stand on the Y axis (No. 7) was most dissimilar to No. 21 and within 10% of it on the X axis. Coefficients of dissimilarity for the Y axis end stands with the remaining 23 were again calculated, followed by arc projection onto the Y axis of the stand locations.

Mean absolute plant cover was believed to be the most informative attribute measured in this study. I believed it was undesirable to complicate the ordination with the introduction of plot frequency values such as in the calculation of indices of Prominence (Beals 1960, Stringer and LaRoi 1970) or Importance (Curtis and McIntosh 1951). In addition, frequency values for certain species were not from comparable plot sizes.



Bannister (1966) discussed some of the advantages of using cover-abundance estimates as a basis for ordination. It allows one to ordinate using Domin or other class values where it is impractical or inefficient to obtain fully objective quantitative information on plant cover and frequency. Bannister believed equally informative ordinations could be constructed using diverse sources of field data, for the following reasons:

- 1) The total species contribution to each stand will tend to reduce the discrepancies between different absolute measures of species contribution,
- 2) When calculating community coefficients, the differences between importance values due to an under-or-over emphasis relative to other methods are likely to be minimized by the averaging process which takes place,
- 3) Large differences in similarity coefficients of different methods when comparing stands to the most similar reference stand are likely to lead only to minor changes on the X axis. Differences in position are likely to be greatest when a particular method of initial measurement causes a reduction of similarity in the relationship of one reference stand and an accentuation of the relationship to the other, as compared to other



methods of initial measurement.

Gimingham, Pritchard, and Cormack (1966) found when ordinating plant communities of a Baltic Sea island, using a method similar to that of Bray and Curtis (1957) that when cover and frequency were used as bases for separate ordinations, the ordination plots yielded the same groupings.

To test the validity of the two-dimensional ordination, a simple correlation coefficient (" $r$ ") was obtained between measured interstand distances and coefficient of dissimilarity for 24 randomly selected stand pairs. The resulting correlation coefficient was  $r = + 0.80$ , significant at the 1% level, indicating that the ordination was a close approximation of the interstand relationships based upon their similarity coefficient, and construction of additional axes was deemed unnecessary.

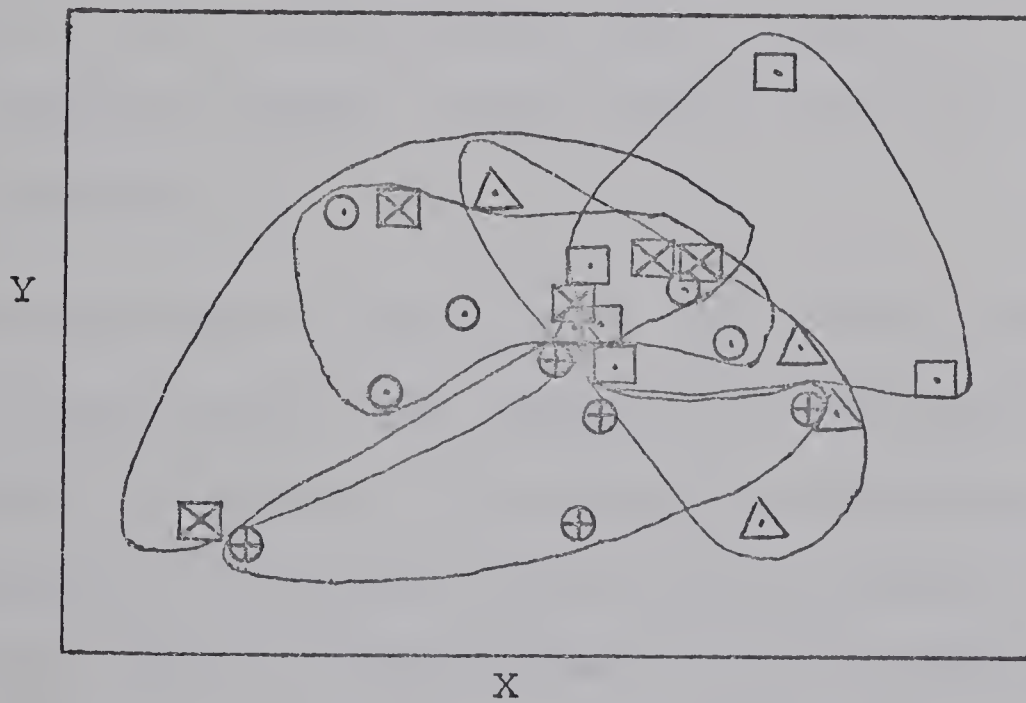
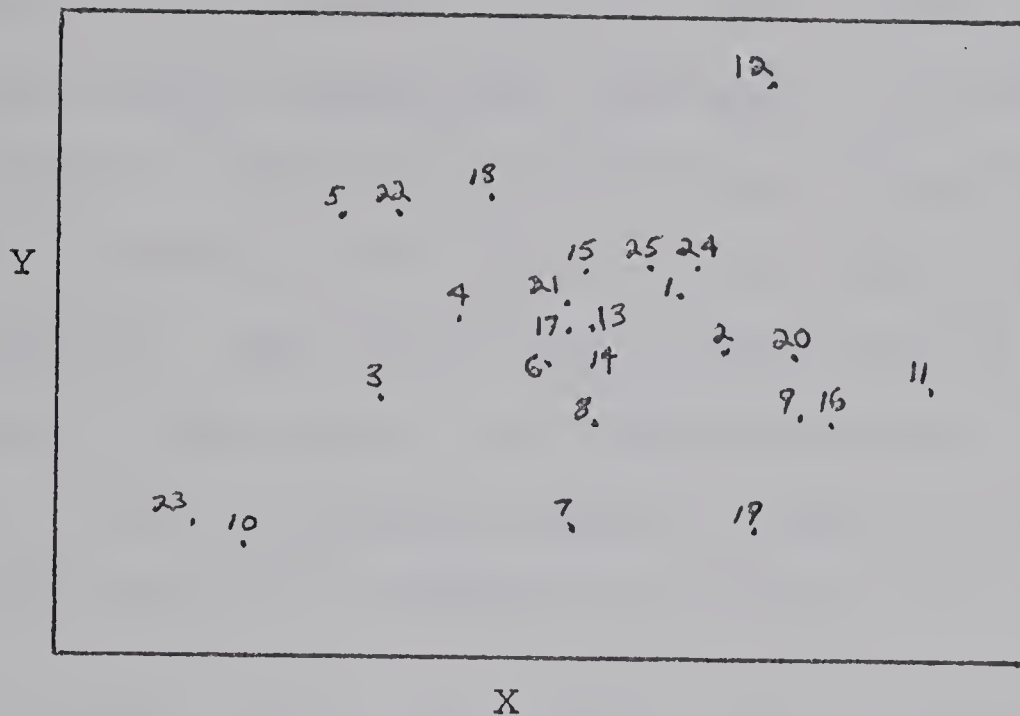
### iii. Discussion

When the ordination is examined, it is apparent that most stands are near the center and but few on the periphery of the XY ordination field (Fig. 10). When cover estimates of species or values of environmental attributes are plotted on the ordination, stand groups and environmental gradients are evident. The stands comprising the groups on the ordination field vary with the different species or environmental attributes plotted.

FIGURE 10. Position of the clearcut stands on the ordination.

FIGURE 11. Stand age groups on the ordination

- - cut 1958-59
- ⊕ - cut 1960-61
- - cut 1961-62
- △ - cut 1963-64
- ⊠ - cut 1964-65





## Stand Age

When stand age is plotted on the XY field, it is apparent that age-groups do exist (Fig. 11). Contiguous age-classes overlap greatly for the first 9 years after logging then become increasingly distinct. For example, stands cleared in 1960-61 lie below those cleared in 1958-59. Stands cleared in 1961-62 lie to the above right of those of 1960-61. The stand group cleared during 1963-64 overlaps that of 1961-62 but is concentrated more to the lower left. The stand group cleared in 1964-65 greatly overlaps that cleared in 1958-59 as viewed on the XY field.

The different groups of the age-classes on the XY field may be due to age-related seral effects or site differences between classes. These effects will be discussed in later chapters.

The overlap of the 1958-59 and 1964-65 groups has important implications with respect to tree regeneration and secondary succession. It suggests a hypothesis that the successional vegetation may not have changed significantly on the older clearcut stands between 1965 and 1970. It is also possible that differences in site quality may be more influential than stand age. Subsequent floristic ordinations lend support to the hypothesis of site differences exerting more influence upon the vegetation than

FIGURE 12a. Field moisture of stands on the ordination.

Progressively larger circles represent classes of 20-25, 26-30, 31-35, 36-40, and more than 40% moisture.

FIGURE 12b. Soil texture of stands on the ordination.

Progressively larger circles represent classes of less than 110, 111-130, 131-150 and more than 150% sand + silt for the A + B horizons.

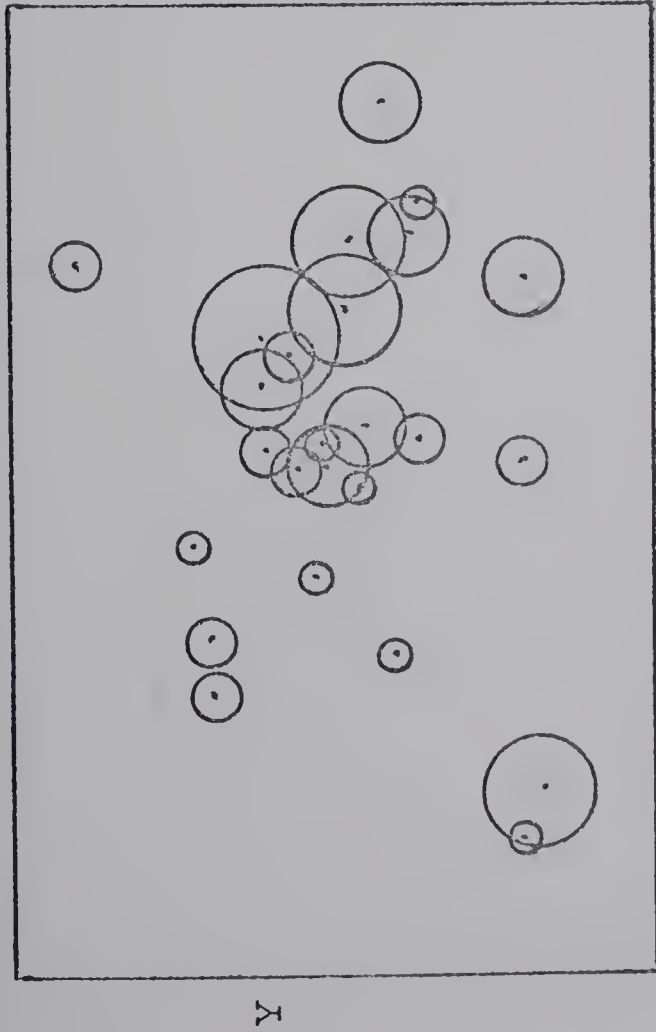
FIGURE 13. Cover of species populations of stands on the ordination.

- a. Total vascular plant cover: progressively larger circles represent classes of 30-50, 51-70, 71-90 and 91-110% cover.
- b. Total moss cover: progressively larger circles represent classes of 1-5, 6-10, 11-15, 16-20 and more than 20% cover.

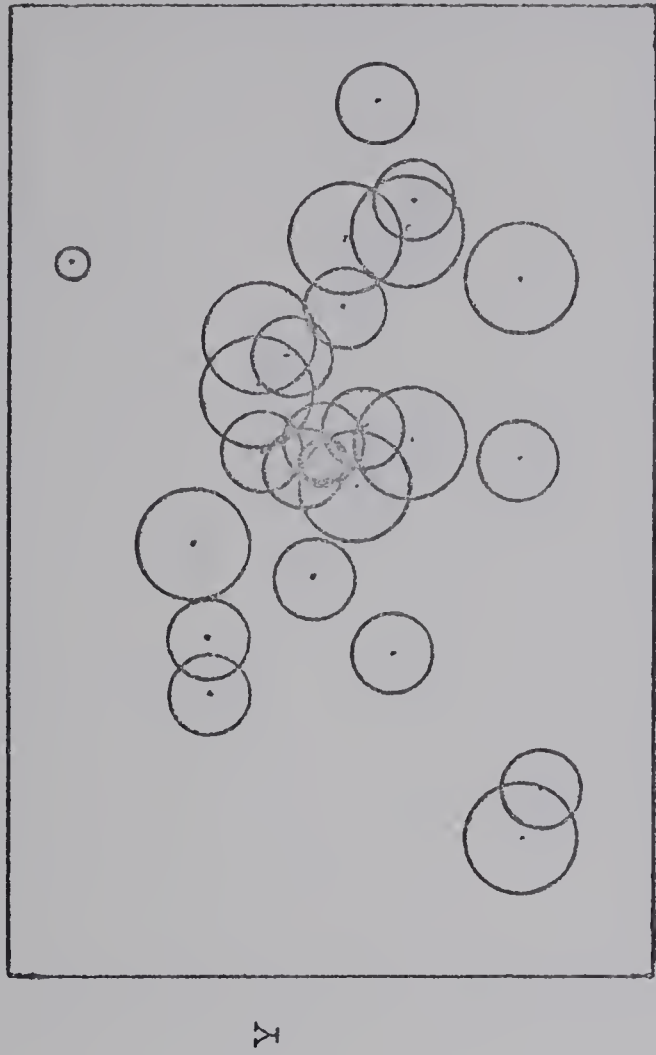
- c. Total lichen cover: progressively larger circles represent classes of 0.0-1.0, 1.1-2.0, 2.1-4.0 and more than 4.0% cover.
- d - s. Individual species populations: progressively larger circles represent classes of less than 1, 1-10, 11-20 and 21-30% cover.



Field soil moisture

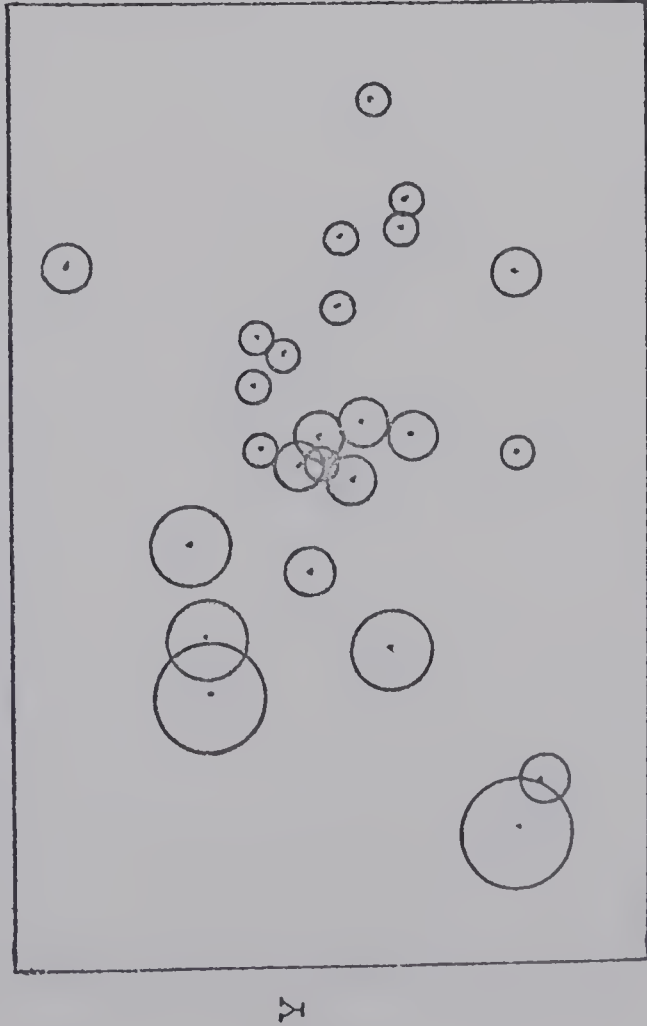


% sand + silt for A + B horizons



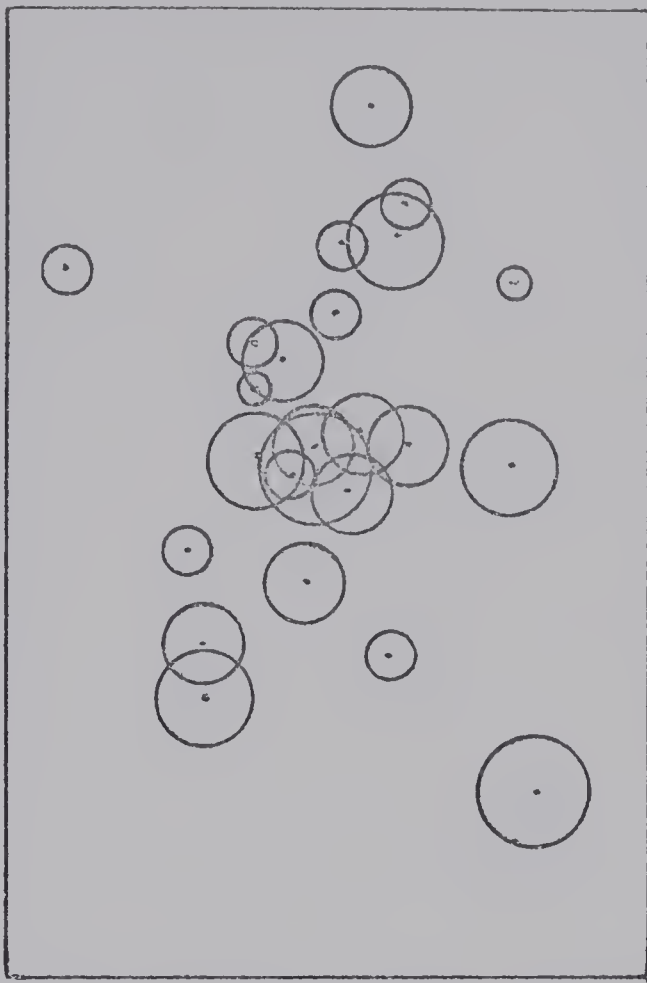
X

a. Vascular plant cover



Y

b. Moss cover



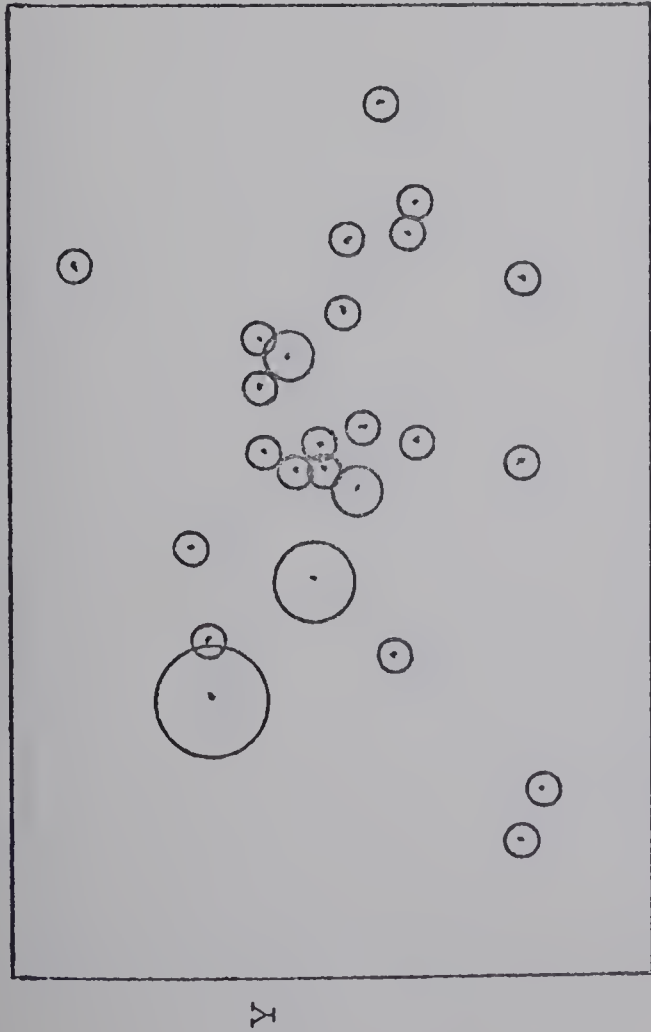
Y

X

X

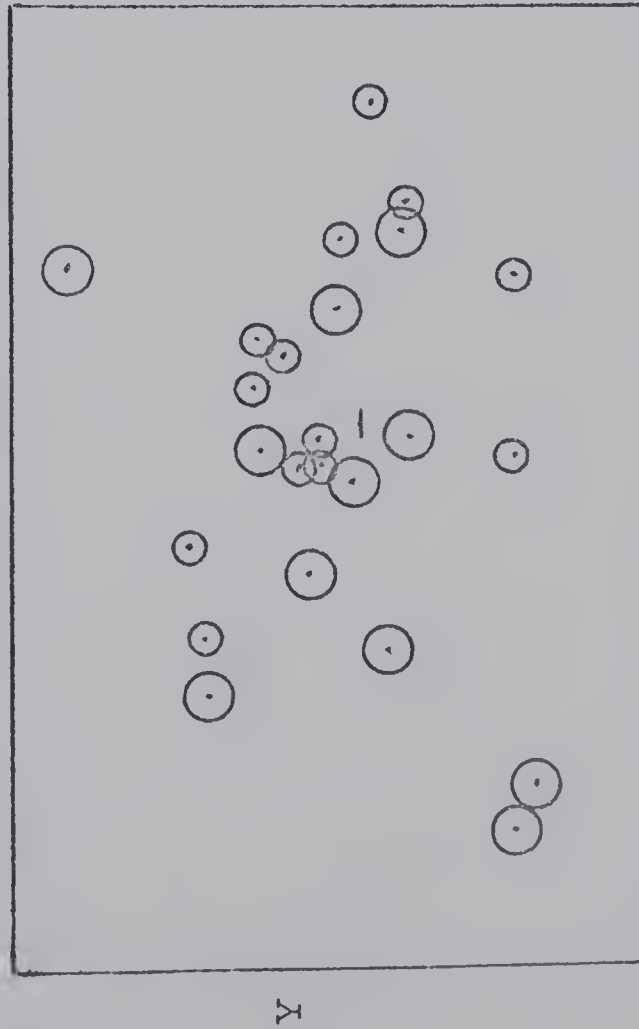


c. Lichen cover



X

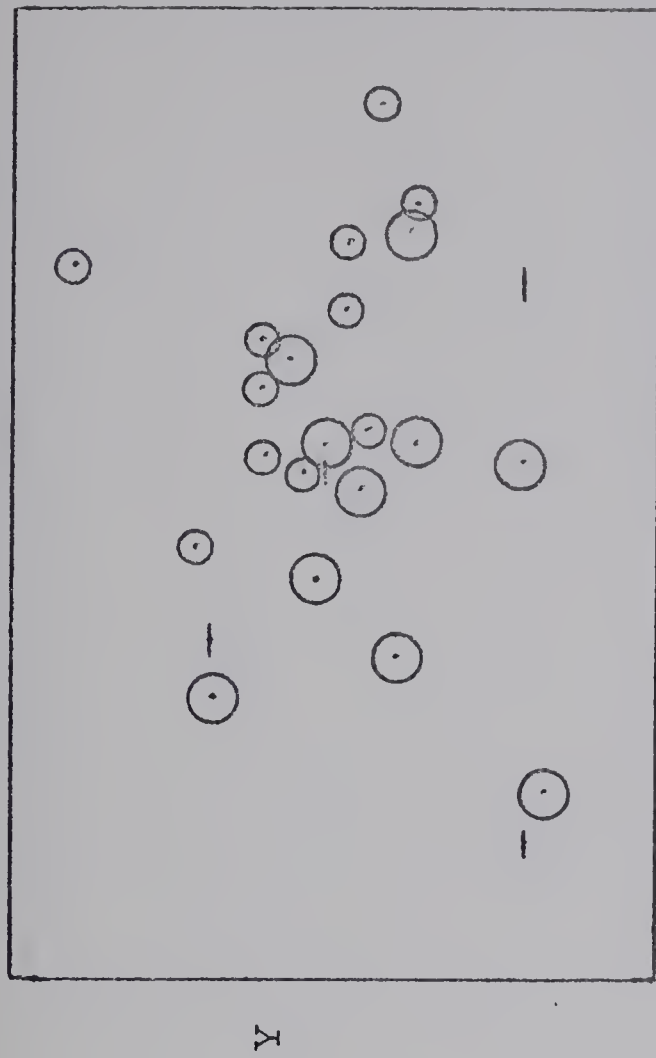
e. *Populus tremuloides* cover



Y

X

d. *Pinus contorta* cover



Y

X

f. *Elymus innovatus* cover

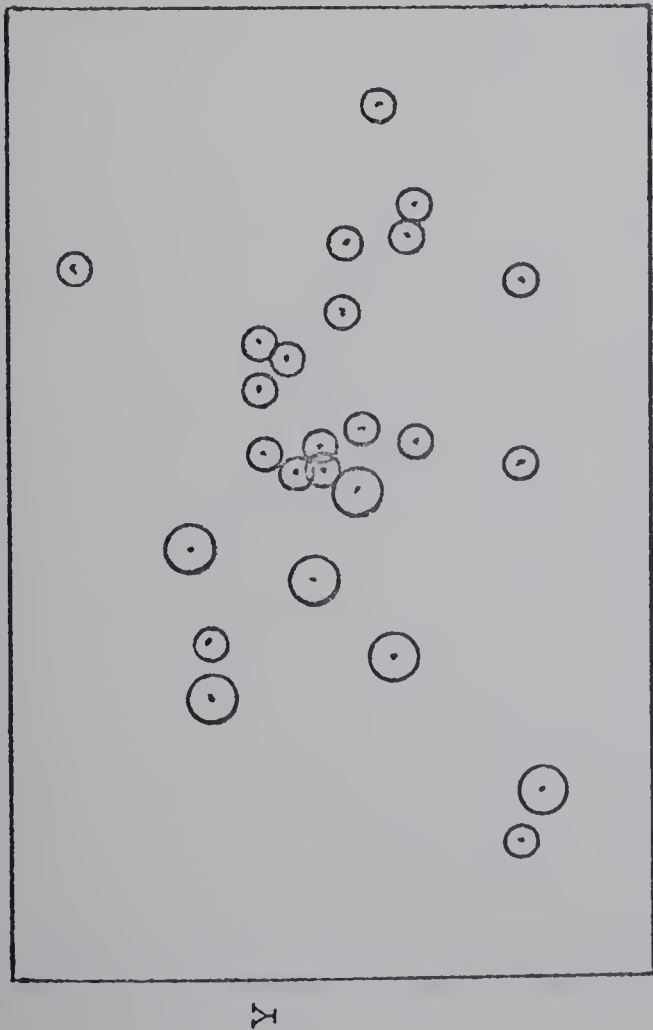


Y

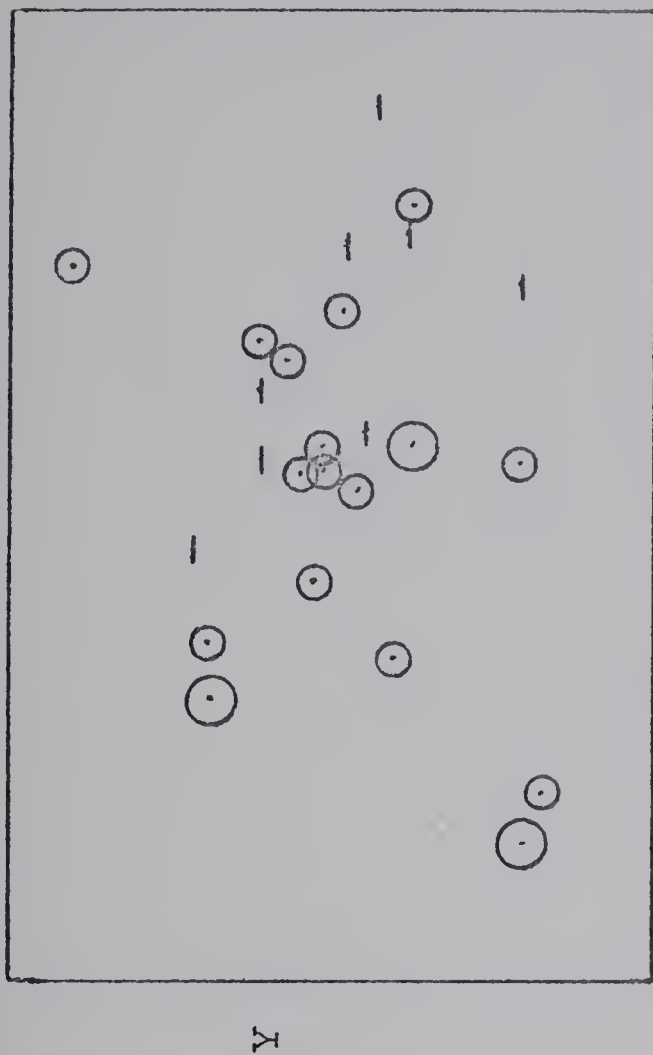
X



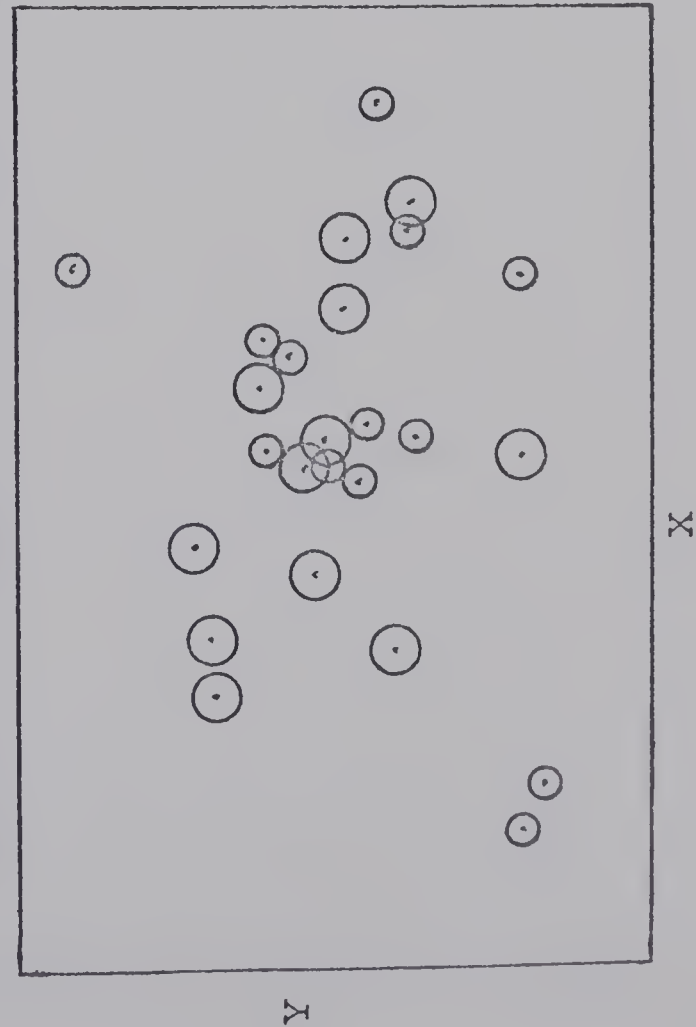
g. *Vaccinium vitis-idaea* cover



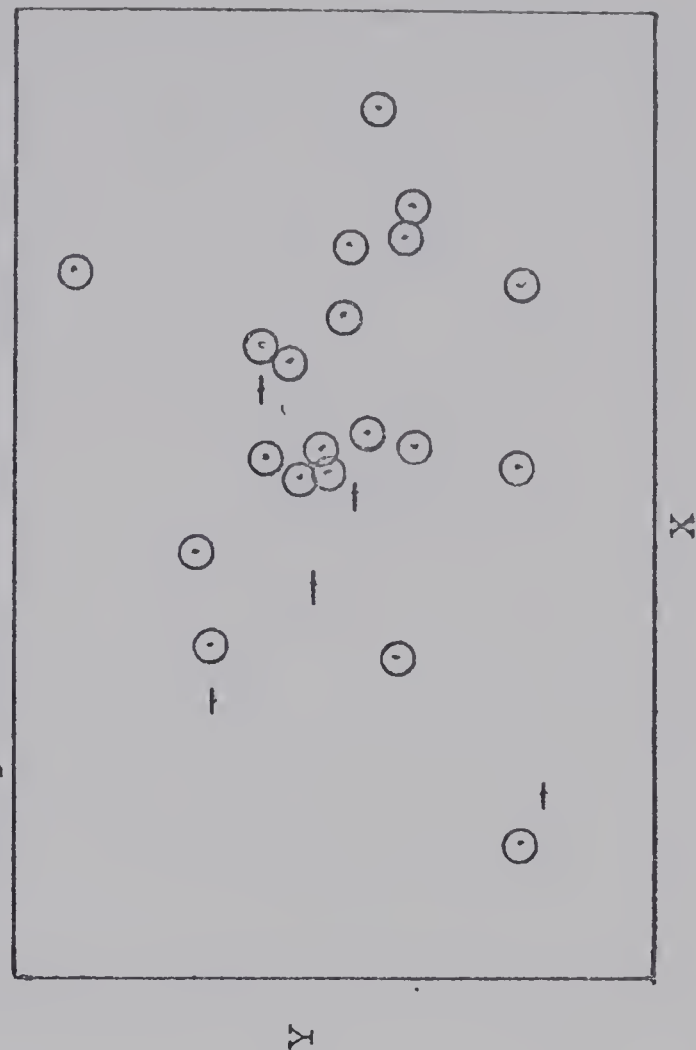
h. *Lathyrus ochroleucus* cover



i. *Linnaea borealis* cover

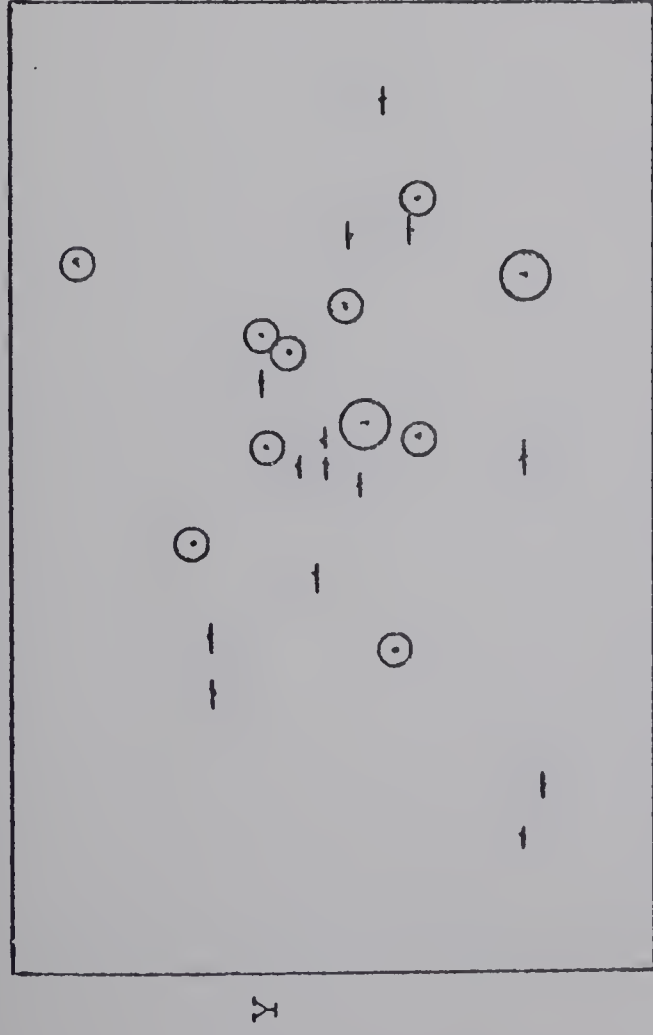


j. *Mitella nuda* cover

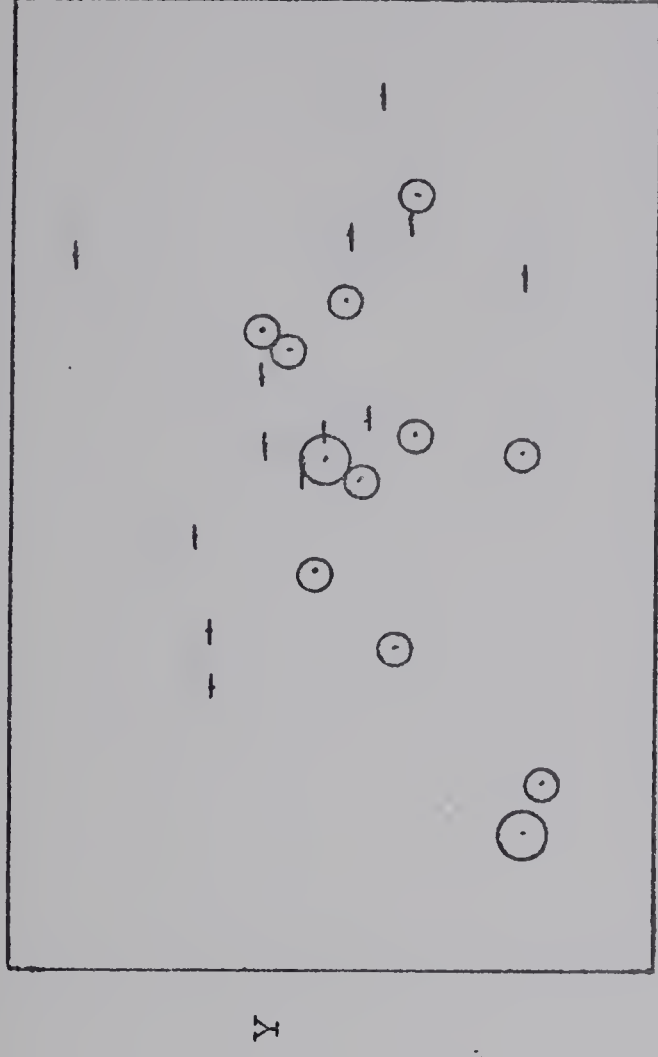




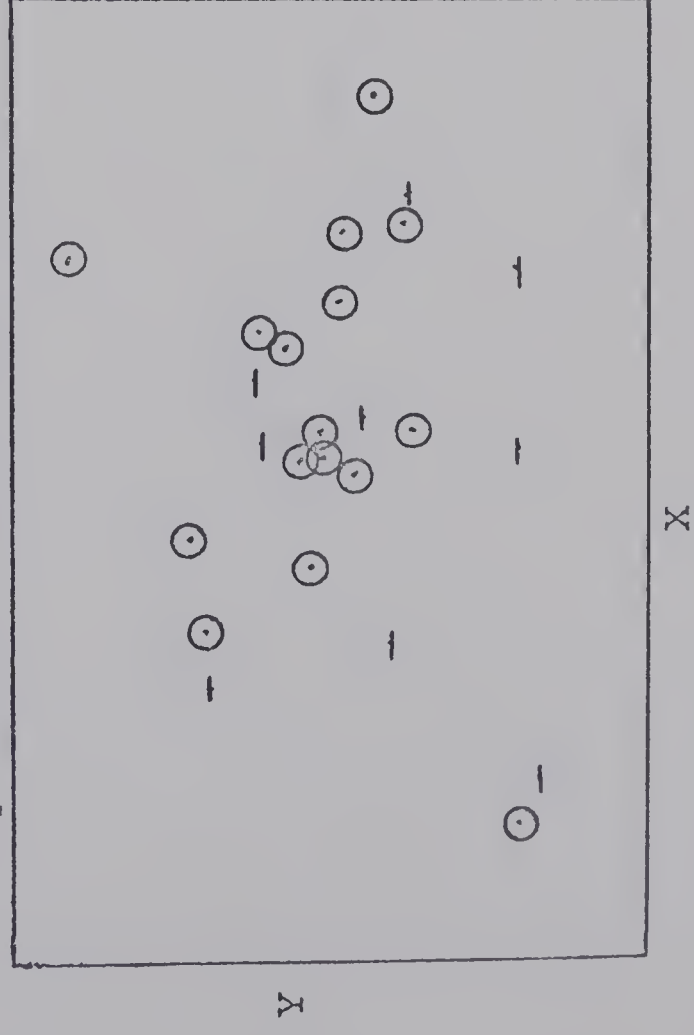
k. *Mertensia paniculata* cover



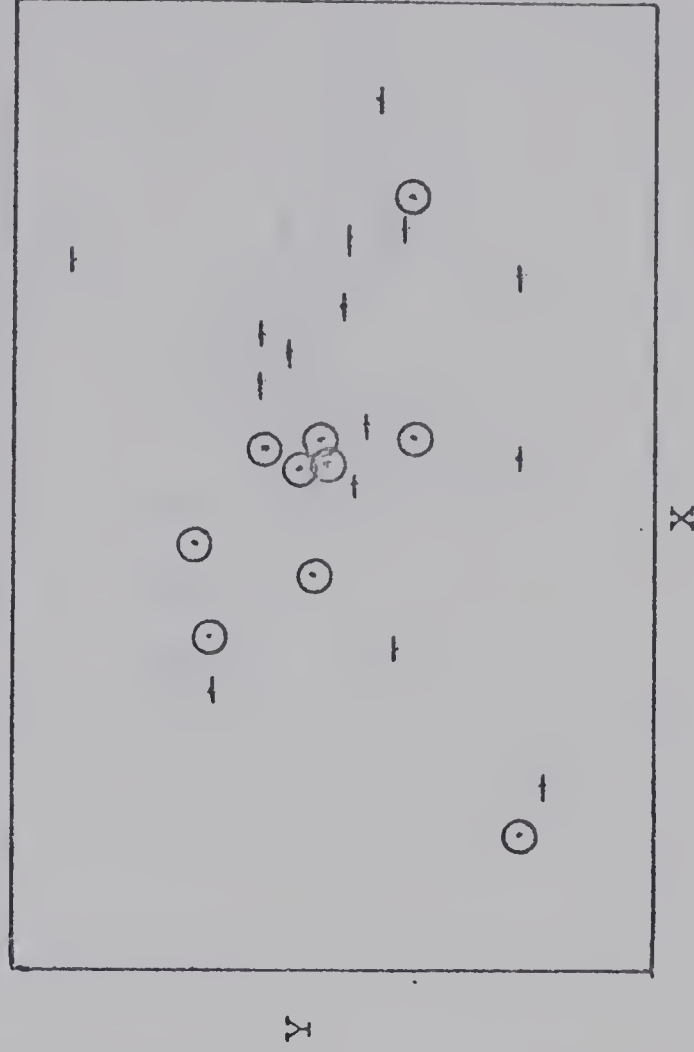
l. *Galium boreale* cover



m. *Populus balsamifera* (over 46cm.) cover

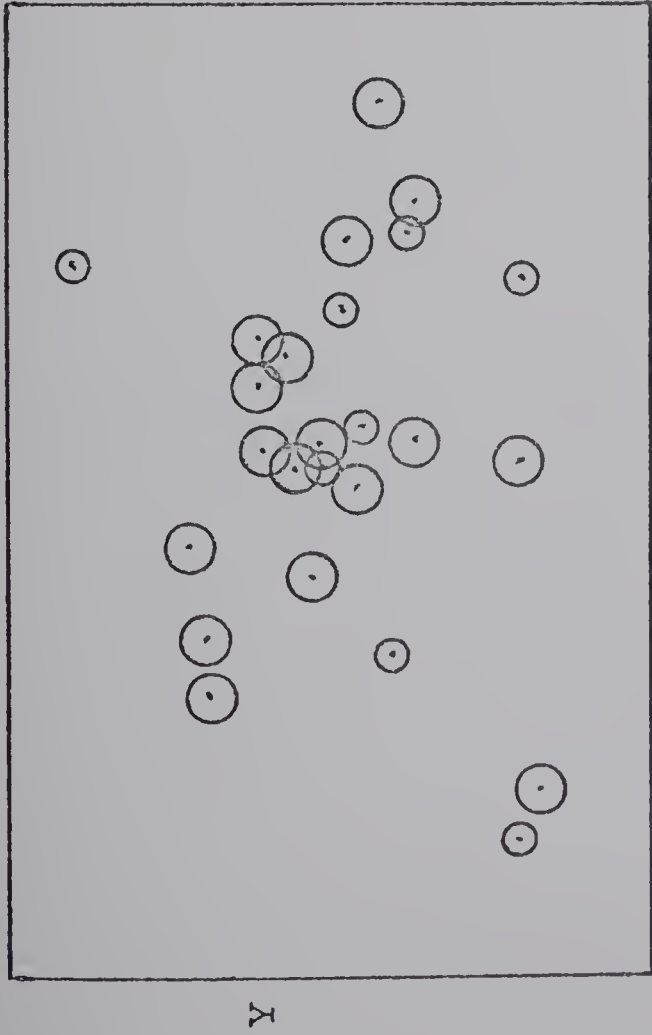


n. *Shepherdia canadensis* (over 46cm.) cover

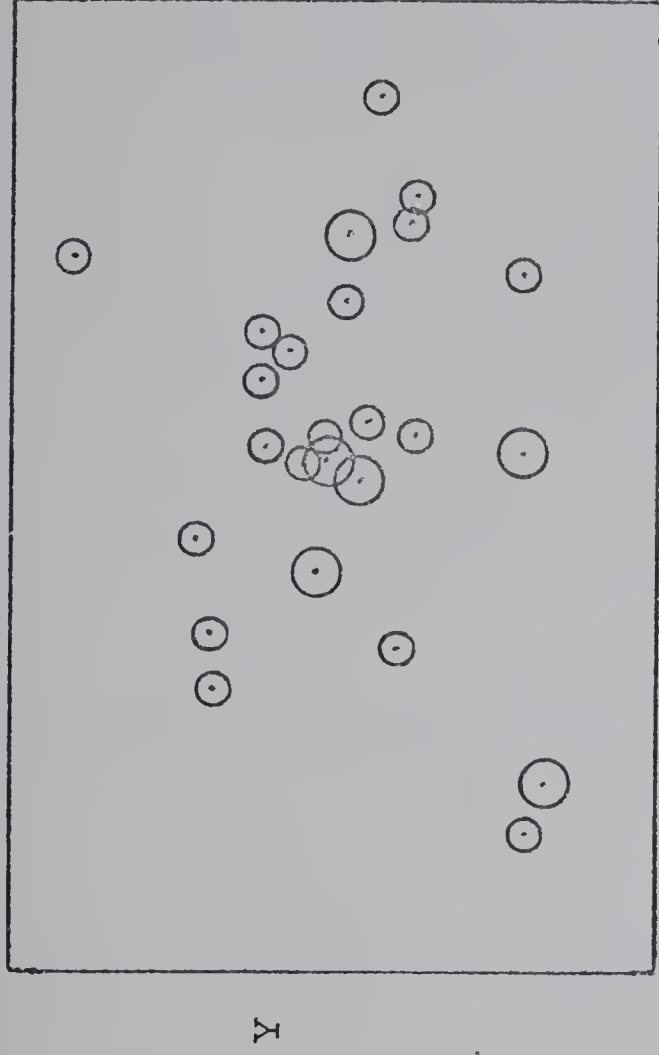




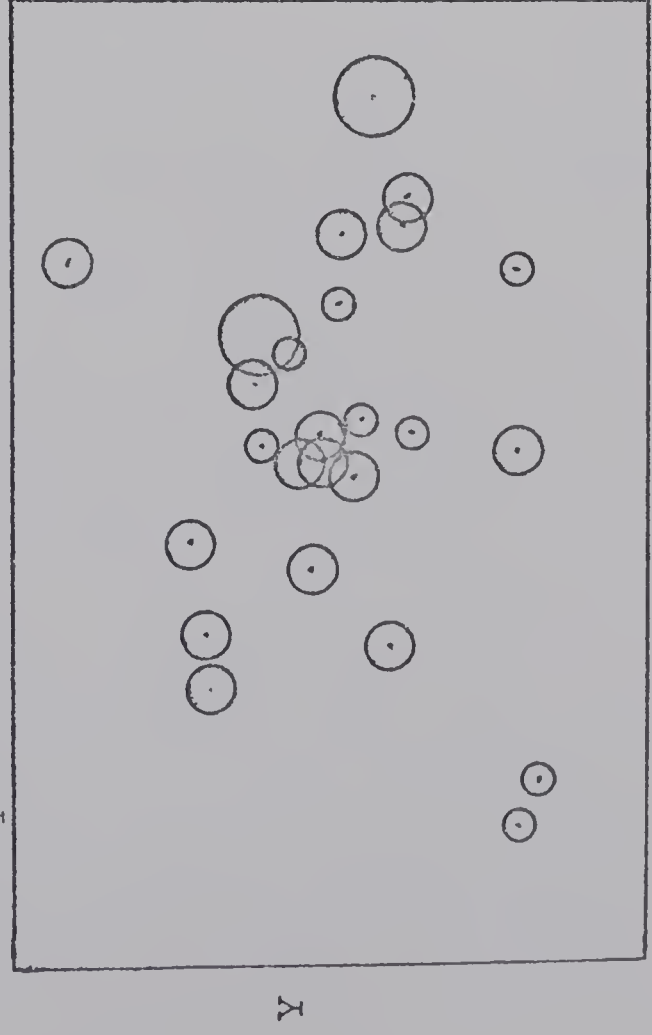
o. *Ledum groenlandicum* cover



p. *Aulacomnium palustre* cover



q. Bare mineral soil cover



r. Bare duff cover

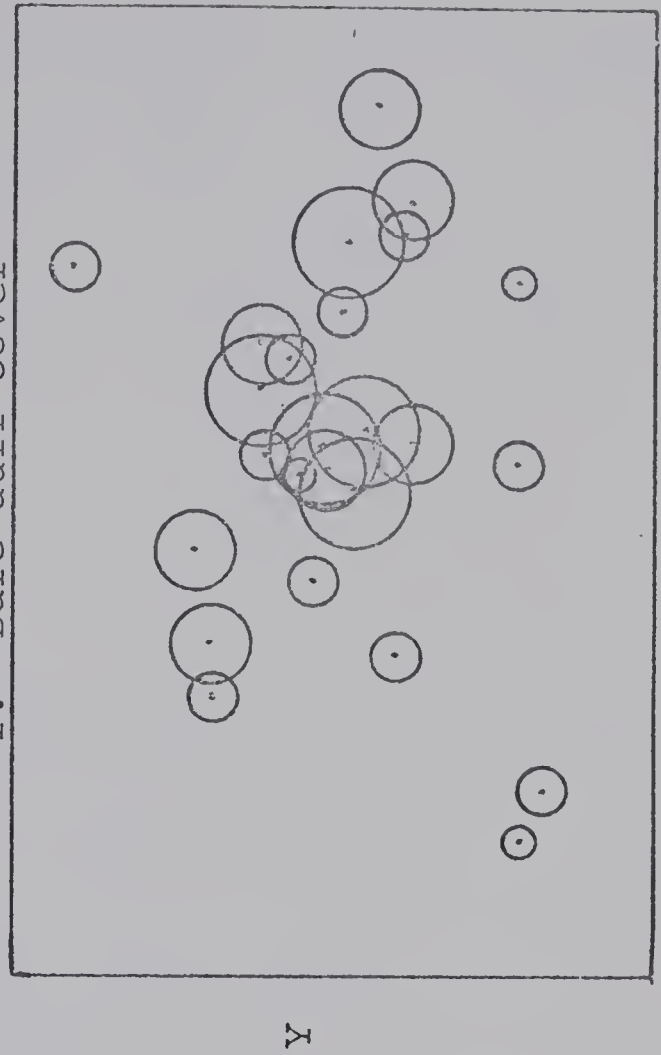


FIGURE 14. Soil nitrogen in the Ae horizon of stands on the ordination.

Progressively larger circles represent classes of 0-3, 3-5, 6-7.5, 8-10 and 11-13 parts per million.

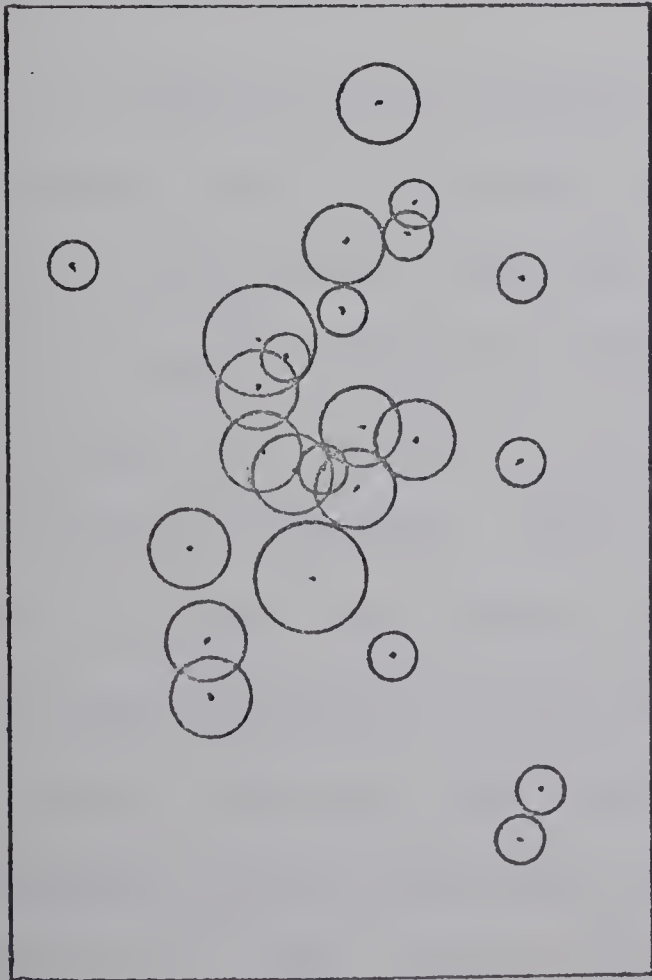
FIGURE 15. Soil phosphorous in the Ae horizon of stands on the ordination.

Progressively larger circles represent classes of 0-5, 6-15, 16-25, 26-35, 36-45 and more than 90 parts per million.

FIGURE 16. Soil potassium in the Ae horizon of stands on the ordination.

Progressively larger circles represent classes of 75-125, 126-175, 176-225, 226-275, 276-325 and more than 325 parts per million.

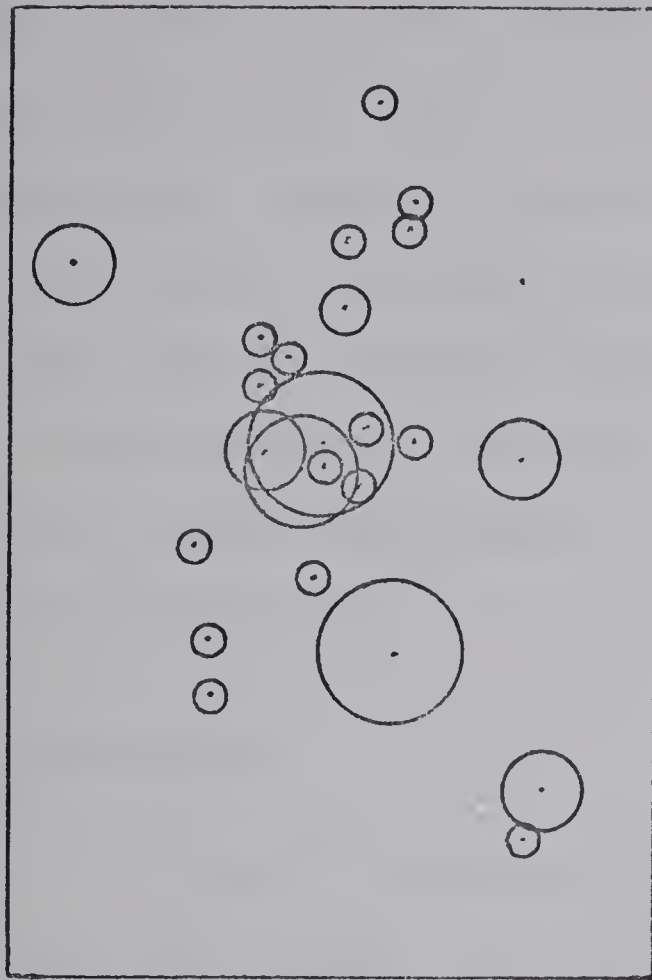
s. slash cover



X

Y

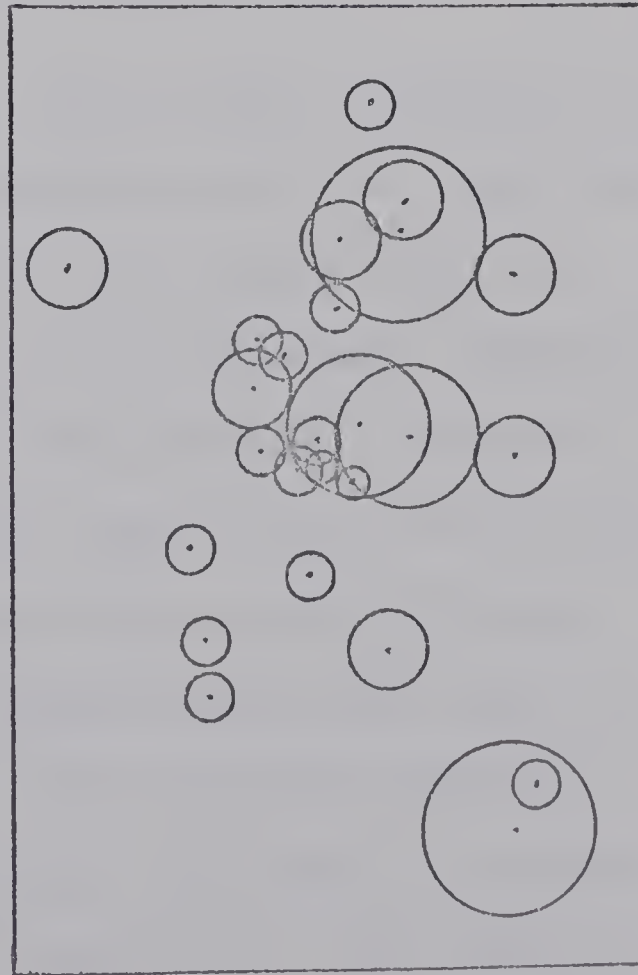
Soil N in Ae horizon



X

Y

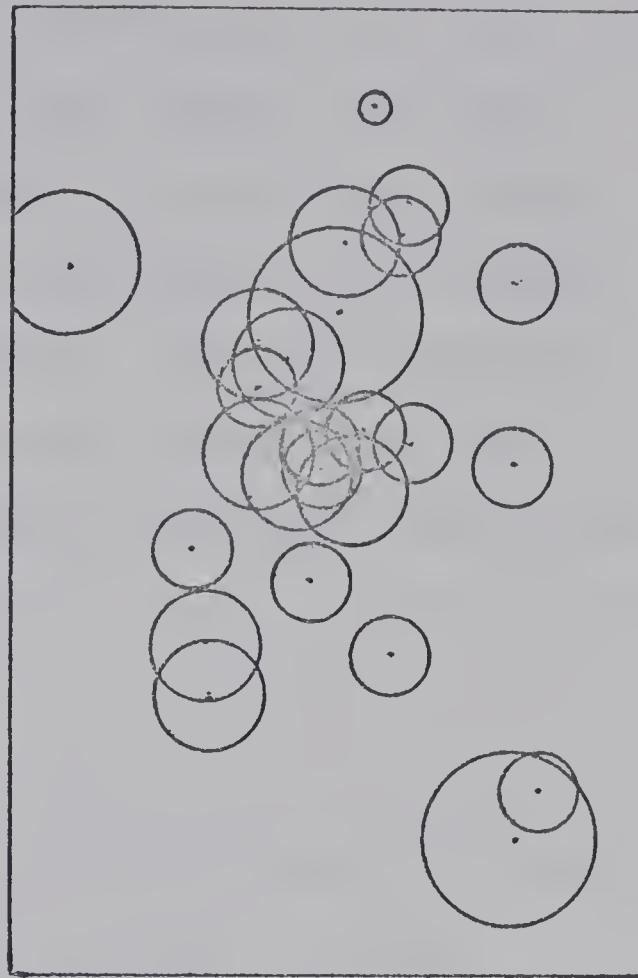
Soil K in Ae horizon



X

Y

Soil P in Ae horizon



X

Y



age. In spite of the grouping for stand age, only two stand attributes, *Vaccinium vitis-idaea* cover, and total lichen cover appear to be influenced by stand age. These two attributes have their greatest abundance in the oldest stands, cleared between 1958 and 1961. All other species and stand attributes show distributions coinciding with physical stand attributes, or exhibit no pattern at all in their distribution.

### Soil Moisture

A plot of the pooled 10 and 20cm gravimetric field soil moisture means for each stand, reveals a strong gradient increasing from left to right across the ordination field (Fig. 12). The soil moisture gradient coincides well with the abundance of several plant species.

Total vascular cover (Fig. 13) is most abundant on the drier sites, reflecting the preference for dry sites of many of the dominant species. Total moss cover (Fig. 13) shows a similar tendency though not as pronounced. Regeneration densities of the two dominant tree species, lodgepole pine taller than 46cm (Fig. 13) and aspen taller than 46cm (Fig. 13) have very similar distributions on the XY field, being most abundant on the drier sites on the left side of the field. Several other species show the same tendency, including *Elymus innovatus*, *Vaccinium vitis-idaea*, *Lathyrus ochroleucus*, and *Linnaea borealis* (Fig. 13). The correla-



tion between *Elymus innovatus* and soil moisture is significant at the 10% level ( $r=-0.446$ ). The distributions of *Mitella nuda* (Fig. 13) and *Mertensia paniculata* (Fig. 13) are mainly on the right side of the ordination field; both are mesophytic and occur in the moister stands.

In addition to the horizontal orientation of several species on the XY field, there appears to be a top-to-bottom orientation involving other species and environmental attributes. The lines separating the stands may vary somewhat depending on the species concerned, reflecting differential response to environmental attributes.

*Galium boreale*, *Populus balsamifera* (over 46 cm ), *Shepherdia canadensis* (over 46 cm ), *Ledum groenlandicum* and *Aulacomium palustre* had their highest cover in stands in either the upper or lower portions of the ordination field (Fig. 13). *Galium boreale* appears to be negatively associated with *Shepherdia canadensis* (over 46 cm ) and positively associated with *Aulacomium palustre*. The distribution of balsam poplar (over 46 cm ) appears to be associated with *Shepherdia canadensis* (over 46 cm ).

Habitat attributes showing a vertical gradient on the ordination field included cover of bare mineral soil, bare duff, and logging slash (Fig. 13). These three stand attributes exhibit an apparent positive association with



each other and with several species. The perhaps unexpected positive association between bare duff cover and bare mineral soil cover is more apparent when viewed as a function of the scarification operation and stand microtopography. As the ground surface is bladed, mineral soil tends to be exposed on mounds and bladed organic material is deposited in the hollows.

Areas where scarification has removed the organic and surface mineral horizon and where the organic layer is deep (i.e., greater than 10cm ), are marginal for plant establishment. Due to the increased fire hazard where slash is heavy, it seems likely that these areas have received more attention during the scarification operation. Although the primary aim of scarification is seedbed preparation, this procedure tends to flatten and break up the boughs rather than incorporate them into the mineral soil. The higher slash cover values on the stands with high cover of bare duff or bare mineral soil can probably be accounted for by the explanation above.

Balsam poplar (over 46 cm ) and *Shepherdia canadensis* (over 46 cm ) are most abundant where slash, bare duff, and bare mineral soil cover is greatest. *Galium boreale* shows the opposite tendency.

In the foregoing discussion, the vertical configuration of plotted attributes suggests the presence of one or more environmental gradients perpendicular to that of field



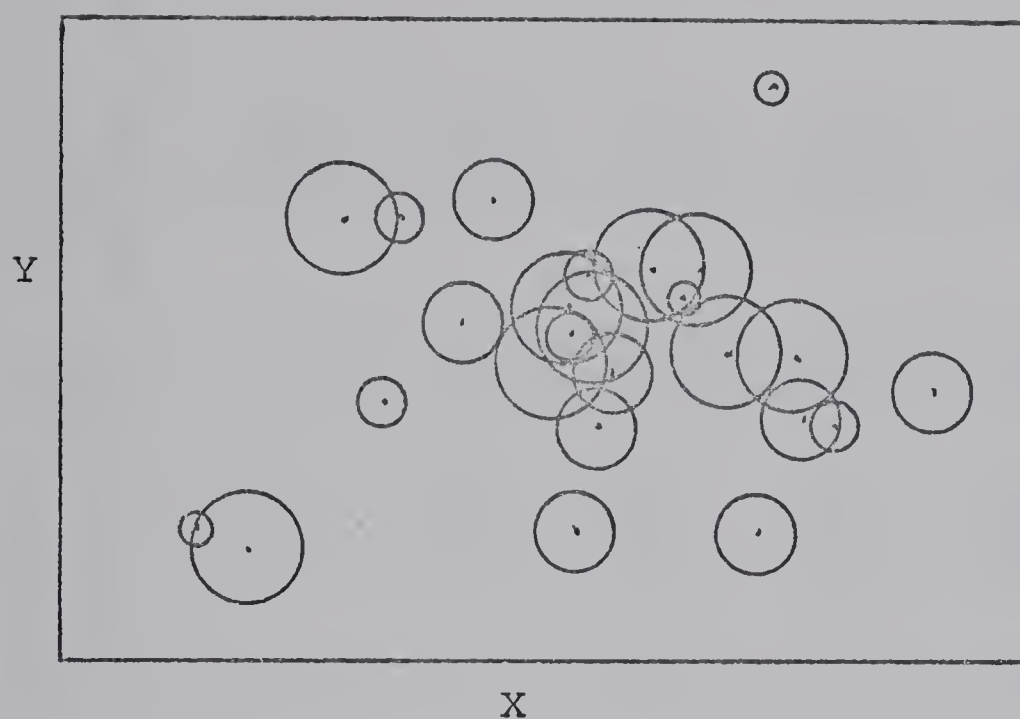


FIGURE 17. Available Soil Moisture in the Ae Horizon

Progressively larger circles represent classes of 12.0-15.0, 15.1-19.0, 19.1-23.0 and 23.1-27.0% available moisture.



TABLE 7. SOILS ATTRIBUTES OF THE CLEARCUT STANDS

Block No.	Stand No.	Horizon Type	Horizon			Texture (%)	Si C	Textural Class	Nutrients (p.p.m)			pH Field Kit	Available Soil Moisture		Gravimetric Field Moisture (%)	% Rock in pit
			Depth (cm)	S	Texture				N	P	K		Moisture	Moisture		
2	1	L-H	0-8	--	--	--	--	Or	--	--	--	5.0	--	--	30	55
		Ae	8-15	32	40	28	28	Cl	1	32	155	4.5	13.2	13.2		
		Bt	15-61	40	29	31	31	Cl	--	--	--	4.5	14.9	14.9		
		C	61+	66	13	21	21	SCl	--	--	--	6.0	8.3	8.3		
5	2	L-H	0-5	--	--	--	--	Or	--	--	--	5.5	--	--	40	35
		Ae	5-13	36	42	22	22	L	4	47	140	6.0	23.5	23.5		
		Bt	13-30	31	28	41	41	C	--	--	--	6.0	13.9	13.9		
		C	30+	32	28	40	40	C	--	--	--	6.0	17.3	17.3		
6	3	L-H	0-5	--	--	--	--	Or	--	--	--	6.0	--	--	24	35
		Ae	5-10	28	41	31	31	Cl	11	19	207	6.0	16.6	16.6		
		Bt	10-46	22	27	51	51	C	--	--	--	6.0	16.9	16.9		
		C	46-91	27	26	48	48	C	--	--	--	6.0	17.2	17.2		
7	4	L-H	0-5	--	--	--	--	Or	--	--	--	5.0	--	--	22	30
		Ae	5-10	35	49	16	16	L	1	16	163	5.5	21.0	21.0		
		Bt	10-51	33	25	42	42	C	--	--	--	6.0	14.6	14.6		
		C	51-122	45	26	29	29	Cl	--	--	--	6.0	12.6	12.6		
9	5	L-H	0-5	--	--	--	--	Or	--	--	--	5.0	--	--	27	10
		Ae	5-13	31	50	19	19	L	1	28	135	6.5	22.1	22.1		
		Bt	13-41	21	42	37	37	Cl	--	--	--	6.0	16.7	16.7		
		C	41+	32	18	50	50	C	--	--	--	6.0	13.5	13.5		
1N	6	L-H	0-5	--	--	--	--	Or	--	--	--	4.5	--	--	25	40
		Ae	5-10	24	57	18	18	SiL	1	26	88	4.5	24.2	24.2		
		Bt	10-41	18	40	42	42	C	--	--	--	6.5	15.9	15.9		
		C	41+	35	26	39	39	Cl	--	--	--	6.5	17.0	17.0		



TABLE 7. Cont'd.

Block No.	Stand No.	Horizon Type	Horizon		Texture (%)			Textural Class	Nutrients (p.p.m)			pH Field Kit	Available Soil Moisture		Gravimetric Field Moisture (%)	% Rock in pit
			Depth (cm)	S	Si	C	C		N	P	K		Moisture	Moisture		
2N	7	L-H	0-5	--	--	--	--	Or	--	--	--	4.5	--	--		
		Ae	5-10	32	48	20	20	L	7	23	182	5.0	22.0	28		5
		Bt	10-84	23	49	28	28	Cl	--	--	--	6.0	17.9			
		C	84+	19	39	42	42	C	--	--	--	6.0	16.2			
8N	8	L-H	0-5	--	--	--	--	Or	--	--	--	4.5	--			
		Ae	5-10	23	40	37	37	Cl	2	17	309	6.0	20.0	29		30
		Bt	10-91	19	28	53	53	C	2	12	457	5.5	17.3			
		C	91+	19	32	49	49	C	1	16	379	5.5	17.9			
11	9	L-H	0-3	--	--	--	--	Or	--	--	--	5.5	--			
		Ae	3-5	18	41	41	41	SiC	1	19	331	5.5	21.4	32		5
		Bt	5-61	*	*	*	*	*	--	--	--	5.5	*			
		C	61+	16	26	58	58	C	--	--	--	6.0	21.6			
12	10	L-H	0-5	--	--	--	--	Or	--	--	--	4.5	--			
		Ae	5-10	29	52	19	19	L	6	22	133	4.5	29.4	40		35
		Bf	10-18	36	52	12	12	SiL	--	--	--	5.5	28.3			
		Bt	18-91	33	32	35	35	Cl	--	--	--	6.5	14.7			
10N	11	C	91+	24	27	49	49	C	--	--	--	5.5	18.4			
		L-H	0-5	--	--	--	--	Or	--	--	--	4.5	--			
		Ae	5-10	29	52	19	19	L	2	4	132	5.0	22.2	31		5
		Bt	10-46	23	28	49	49	C	--	--	--	5.0	17.8			
22	12	C	46+	20	35	45	45	C	--	--	--	5.5	15.4			
		L-H	0-8	--	--	--	--	Or	--	--	--	5.5	--			
		Ae	8-13	51	24	25	25	SiCl	2	37	197	5.5	13.3	27		40
		B-C	13+	65	17	18	18	SiCl	--	--	--	5.5	12.8			



TABLE 7. Cont'd.

Block No.	Stand No.	Horizon Type	Horizon Depth (cm)	Texture			Textural Class	Nutrients (p.p.m)			pH Field Kit	Available Soil Moisture		Gravimetric Field Moisture (%)	% Rock in pit
				S	Si	C		N	P	K		Moisture	Moisture		
28	13	L-H	0-5	--	--	--	Or	--	--	--	5.5	--	--	23	15
		Ae	5-10	29	48	23	l	13	24	160	5.5	23.3			
		Bf	10-36	25	41	34	Cl	--	--	--	6.0	18.2			
		Bt	36-57	21	29	50	C	--	--	--	6.0	15.4			
		C	57+	57	24	19	SCl	--	--	--	6.0	15.1			
32	14	L-H	0-5	--	--	--	Or	--	--	--	4.5	--	--	33	15
		Ae	5-13	13	43	44	SiCl	1	16	321	6.0	20.0			
		Bt	13-30	37	22	41	C	--	--	--	5.5	18.9			
		C	30+	15	30	55	C	--	--	--	5.5	19.5			
		L-H	0-5	--	--	--	Or	--	--	--	5.5	--			
9N	15	Ae	5-8	30	49	21	L	6	30	135	5.5	16.9	29	35	
		Bt	8-56	29	29	42	C	--	--	--	5.5	15.2			
		C	56+	47	16	37	Cl	--	--	--	5.5	12.9			
		L-H	0-5	--	--	--	Or	--	--	--	5.5	--			
		Ae	5-8	28	43	29	Cl	1	24	204	5.5	16.2			
60	16	Bt	8-30	22	37	41	C	--	--	--	5.5	18.3	25	0	
		C	30+	24	31	35	C	--	--	--	6.0	16.5			
		L-H	0-5	--	--	--	Or	--	--	--	5.5	--			
		Ae	5-8	28	43	29	Cl	1	24	204	5.5	16.2			
		Bt	8-30	22	37	41	C	--	--	--	5.5	18.3			
68	17	C	30+	24	31	35	C	--	--	--	6.0	16.5	31	10	
		L-H	0-5	--	--	--	Or	--	--	--	4.5	--			
		Ae	5-10	42	42	16	L	1	18	109	5.5	18.6			
		Bt-C	10-51	32	27	41	C	--	--	--	6.0	14.3			
		L-H	0-5	--	--	--	Or	--	--	--	4.5	--			
114	18	Ae	5-10	21	58	21	SiL	2	25	168	5.5	20.6	25	30	
		Bt	10-46	59	14	27	SCl	--	--	--	5.5	18.5			
		C	46+	*	*	*	SCl	--	--	--	5.5	13.7			
		L-H	0-5	--	--	--	Or	--	--	--	4.5	--			
		Ae	5-10	21	58	21	SiL	2	25	168	5.5	20.6			
116	19	Bt	10-46	59	14	27	SCl	--	--	--	5.5	18.5	34	5	
		C	46+	*	*	*	SCl	--	--	--	5.5	13.7			
		L-H	0-5	--	--	--	Or	--	--	--	4.5	--			
		Ae	5-10	27	51	22	L	2	16	191	5.5	21.1			
		Bt	10-36	18	30	52	C	1	9	381	6.0	17.5			
			36+	32	45	23	L	1	11	167	5.5	22.9			



TABLE 7. Cont'd.

Block No.	Stand No.	Horizon Type	Horizon		Texture (%)			Textural Class	Nutrients (p.p.m.)			pH Field Kit	Available Soil Moisture		Field Moisture (%)	Gravimetric Moisture (%)	Rock in pit
			Depth (cm)	S	Si	C	C		N	P	K		Moisture	Moisture			
121	20	L-H Ae Bf Bt C	0-5 5-10 10-25 25-107 107+	-- 30 18 9 *	-- 43 34 45 *	-- 27 48 46 *	-- Or Cl C SiC SiC	Or	-- 2 -- -- -- --	-- 30 -- -- -- --	-- 190 -- -- -- --	4.5 4.5 -- 6.0 5.5	-- 23.5 21.6 17.2 17.2	--	37		10
71	21	L-H Ae Bt C	0-5 5-10 10-25 25+	-- 36 28 27	-- 47 28 30	-- 17 44 43	-- Or L C C	Or	-- 9 -- -- --	-- 31 -- -- --	-- 149 -- -- --	4.5 6.5 6.0 6.0	-- 23.7 13.7 16.1	--	27		30
102	22	L-H Ae Bt C	0-5 5-15 15-46 46+	-- 34 24 67	-- 44 27 14	-- 22 49 19	-- Or L C SCL	Or	-- 2 -- -- --	-- 30 -- -- --	-- 149 -- -- --	6.5 6.5 6.0 6.0	-- 18.6 23.6 9.9	--	27		30
103	23	L-H Ae Bt C	0-5 5-13 13-46 46+	-- * 15 30	-- * 25 26	-- * 60 44	-- Or * HC C	Or	-- 2 -- -- --	-- 52 -- -- --	-- 359 -- -- --	6.5 6.5 6.5 6.5	-- * 24.4 14.5	--	23		30
122	24	L-H Ae Bt C	0-5 5-10 10-41 41+	-- 26 20 16	-- 52 53 43	-- 22 27 41	-- Or L Cl SiC	Or	-- 1 -- -- --	-- 26 -- -- --	-- 141 -- -- --	4.5 4.5 5.5 6.0	-- 26.1 18.6 19.0	--	46		
123	25	L-H Ae Bt C Bedrock	0-5 5-10 10-46 46-61 61+	-- 27 17 22 43	-- 45 40 34 37	-- 28 43 44 20	-- Or Cl C C L	Or	-- 2 -- -- -- --	-- 17 -- -- -- --	-- 200 -- -- -- --	4.5 4.5 6.0 6.0 6.5	-- 25.5 20.1 17.6 18.2	--	34		10

\* - Sample missing; Or - Organic; S - Sand; Si - Silt; C - Clay; L - Loam.



soil moisture.

The major soil nutrients ——— nitrogen, phosphorous and potassium in the Ae horizon (Table 7) do not show trends as pronounced as some other attributes on the ordination field. Soil potassium (Fig. 14) shows a slight tendency to decrease from lower right to upper left on the field. Phosphorous (Fig. 15) is greater than 25 ppm. in the upper part of the field where bare duff and slash cover is greatest, suggesting soil replenishment of these nutrients by organic matter decomposition or possibly non-utilization by plant life because of other limiting factors. Soil potassium and phosphorous could be factors accounting for the vertical distributions of several species and stand attributes. Soil nitrogen (Fig. 16) is highest in the lower left of the field and does not closely approximate the distributions of other species or stand attributes.

Eight of nine stands with available soil moisture over 19% in the Ae horizon are in the upper half of the XY field.

The soil texture (expressed as % sand + silt for the A + B horizons) plot on the ordination most closely resembles the plot of field soil moisture, but the association is not strong. Since available soil moisture (Fig. 17) and field soil moisture are a function of clay content of the soil, the poor correlation of soil texture with soil moisture and

FIGURE 18a. Height and age distribution of the pine population on 12 year old stands

Samples pooled from stands 1, 3 and 4. Number of samples of each age indicated above each column.

FIGURE 18b. Height and age distribution of the aspen population on 12 year old stands.

Samples pooled from stands 1, 3 and 4. Number of samples of each age indicated above each column.

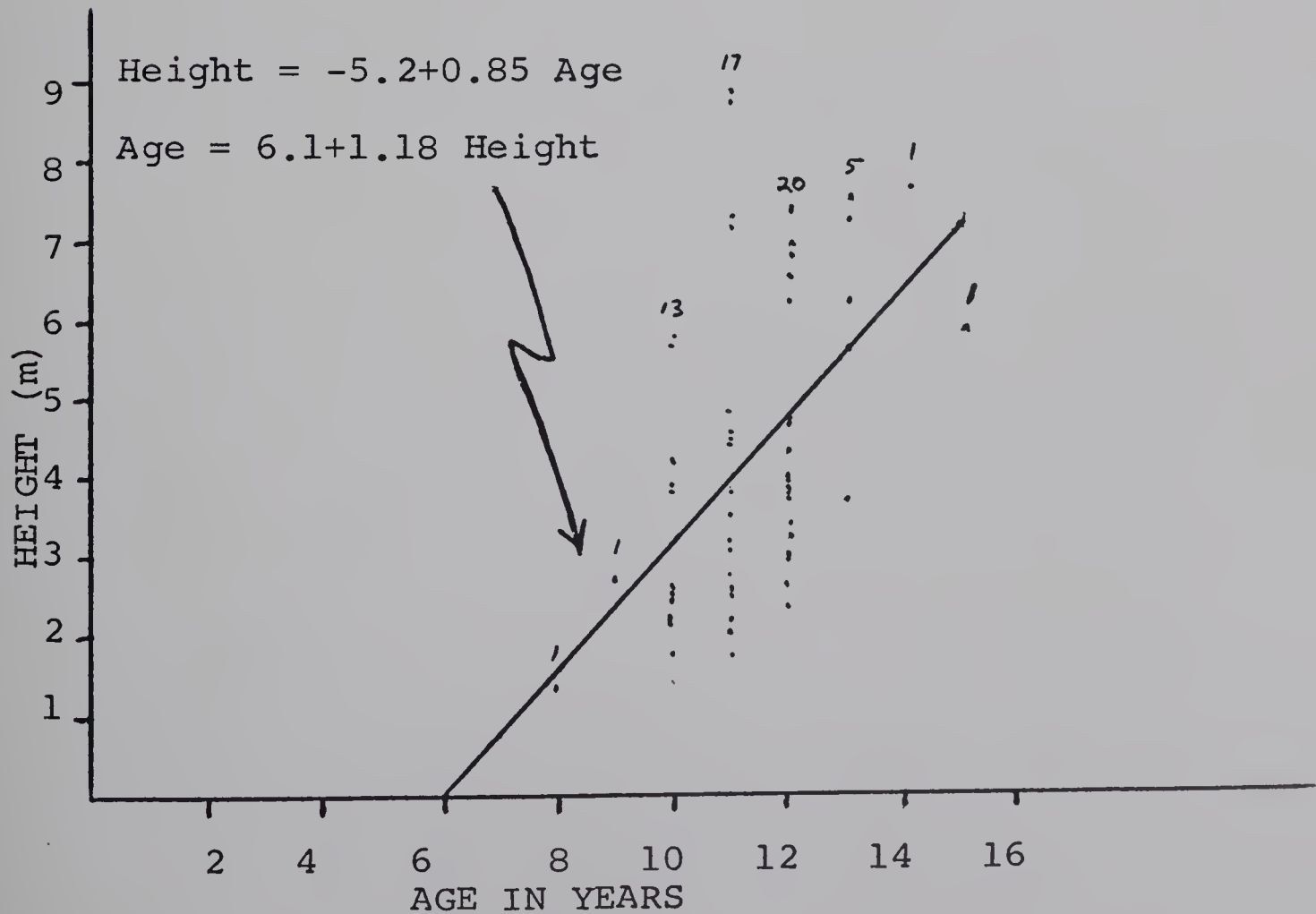
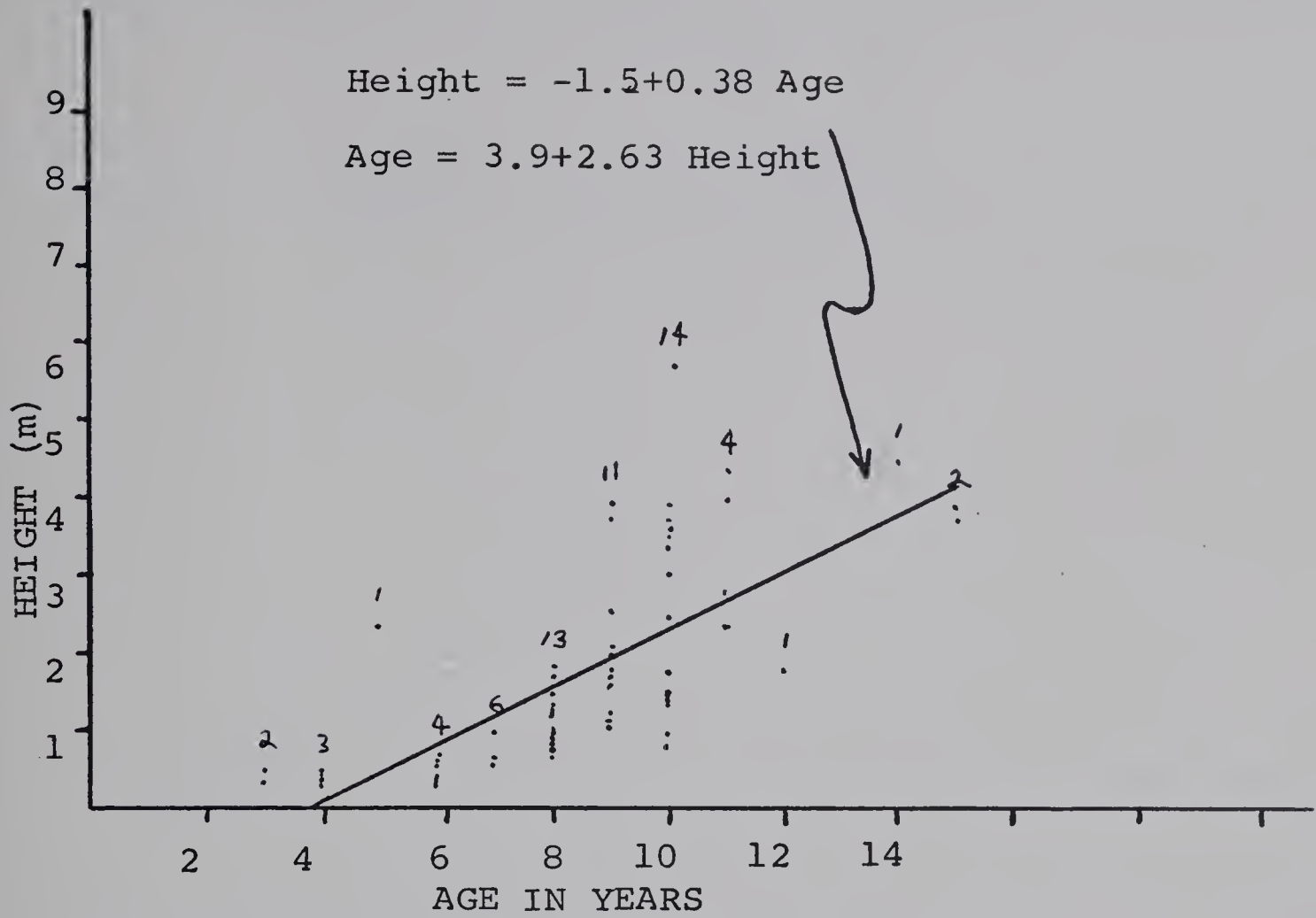
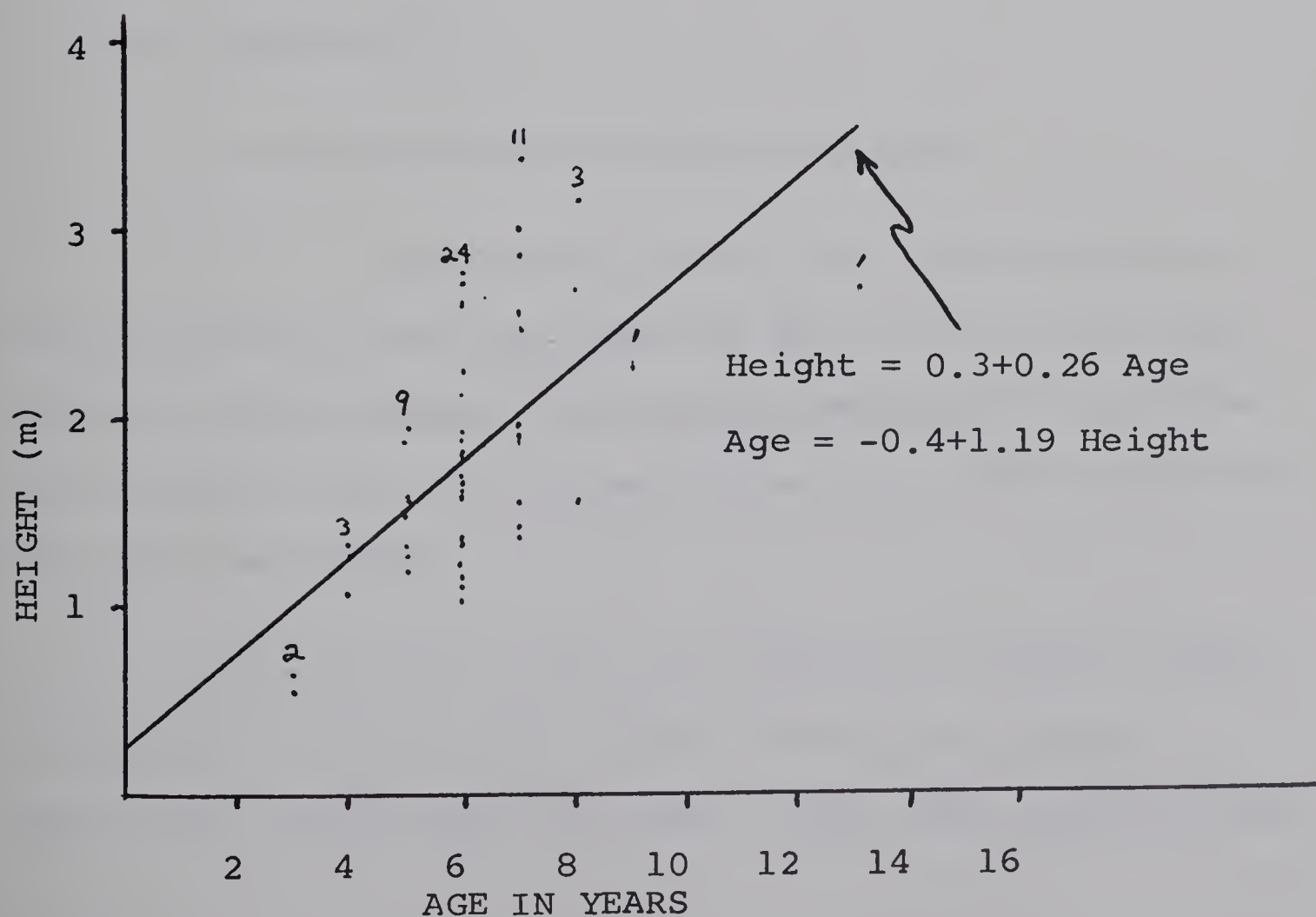
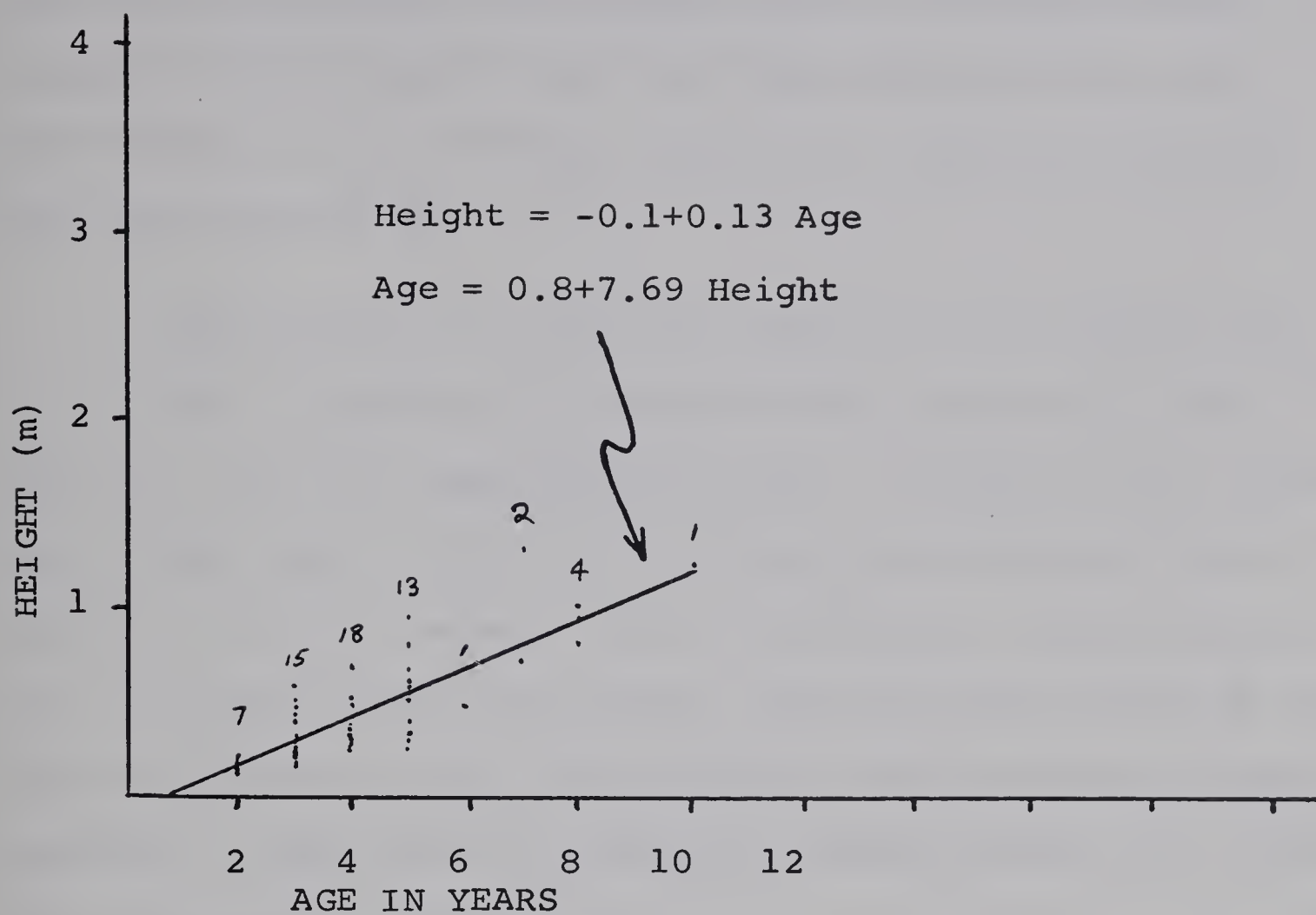


FIGURE 18c. Height and age distribution of the pine population on 6 year old stands.

Samples pooled from stands 21, 23 and 24. Number of samples of each age indicated above each column.

FIGURE 18d. Height and age distribution of the aspen population on 6 year old stands

Samples pooled from stands 21, 23 and 24. Number of samples of each age indicated above each column.





other soil properties is probably due to an insufficient sample for soil texture and soil chemical properties plus differences in soil drainage and profile depth that do not enter the ordination.

The majority of the plant species in the study area do not show a response to environmental gradients or even to stand age, and are approximately equal in cover in all stands. Among those species which do not show any pattern on the ordination are *Viola adunca*, *Cornus canadensis*, *Arctostaphylos uva ursi*, *Vaccinium myrtilloides*, *Viburnum edule* (over 46 cm ), *Epilobium angustifolium*, *Polytrichum commune* and *Maianthemum canadense*. Other species showing a random scatter are evident upon examination of Table 4.

#### D. Tree Regeneration

##### i. Age and Height of Pine and Aspen

Figures 18a to 18d give the height-age relationships of pine and aspen on the 12 and 6 year old stands on which biomass and density estimations were made. The samples of the three stands of each age were pooled for both pine and aspen.

On the 12 and 6 year old stands the largest number of pine are in the 10 (23%) and 4 (30%) year classes respectively indicating that most of the pine natality and



establishment arose in the third summer after the stand was cleared. This is probably due to the time necessary to break the resin bond of the cones on the logging slash, the seed source of the pine stand, resulting in a delay in pine establishment. Crossley (1956) found, however, that cone age had no effect on the ability of the cone to open and that the greatest percentage of slash-borne cones opened during the first year under optimum temperature conditions. Very few openings occurred after the second year.

Other factors may account for the apparent 2 year lag in the size of the pine population. The most significant of these perhaps is the absence of a suitable seed bed for the pine seeds. The block is usually not scarified until at least a year has elapsed after logging. It seems reasonable to expect that as long as the pine seed remains viable, the greatest successful natality will arise after the scarification operation.

The 2 year lag is not apparent for aspen on the 12 and 6 year old stands, with the largest numbers occurring in the 12 (38%) and 6 (70%) year classes respectively. This fact illustrates the competitive advantage of aspen over pine in the very early successional stages, reflecting the vegetative reproduction of the species.

The linear regressions of height on age for pine and

FIGURE 19. Height class distribution of pine (solid line) and aspen (dotted line) regeneration density in stand 24

Pine density - 6200 stems/ha

Aspen density - 1300 stems/ha

Figures on vertical axis are thousands of stems/ha

FIGURE 20. Height class distribution of pine (solid line) and aspen (dotted line) regeneration biomass in stand 24

Pine biomass - 60 kg/ha

Aspen biomass - 7 kg/ha

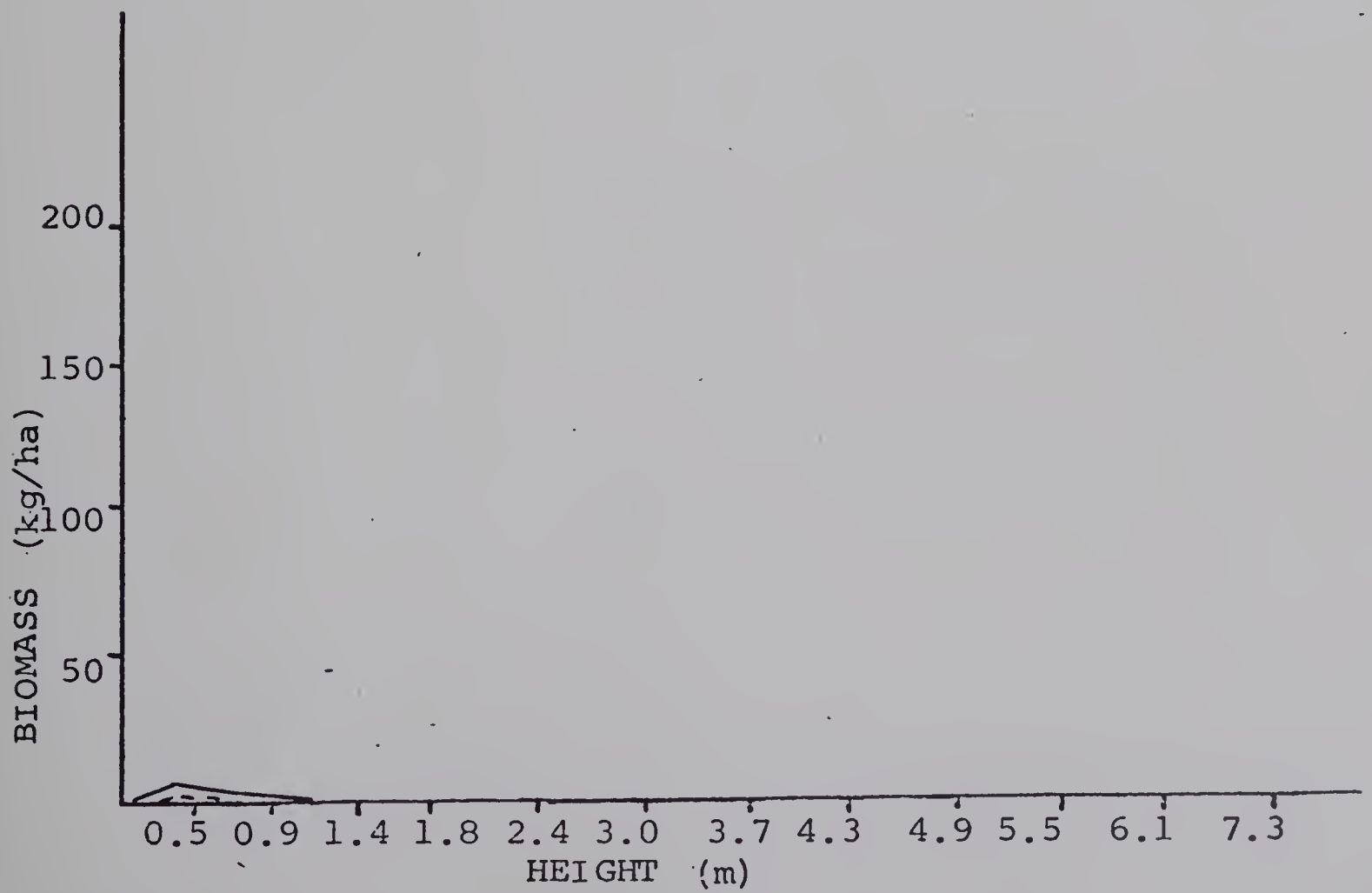
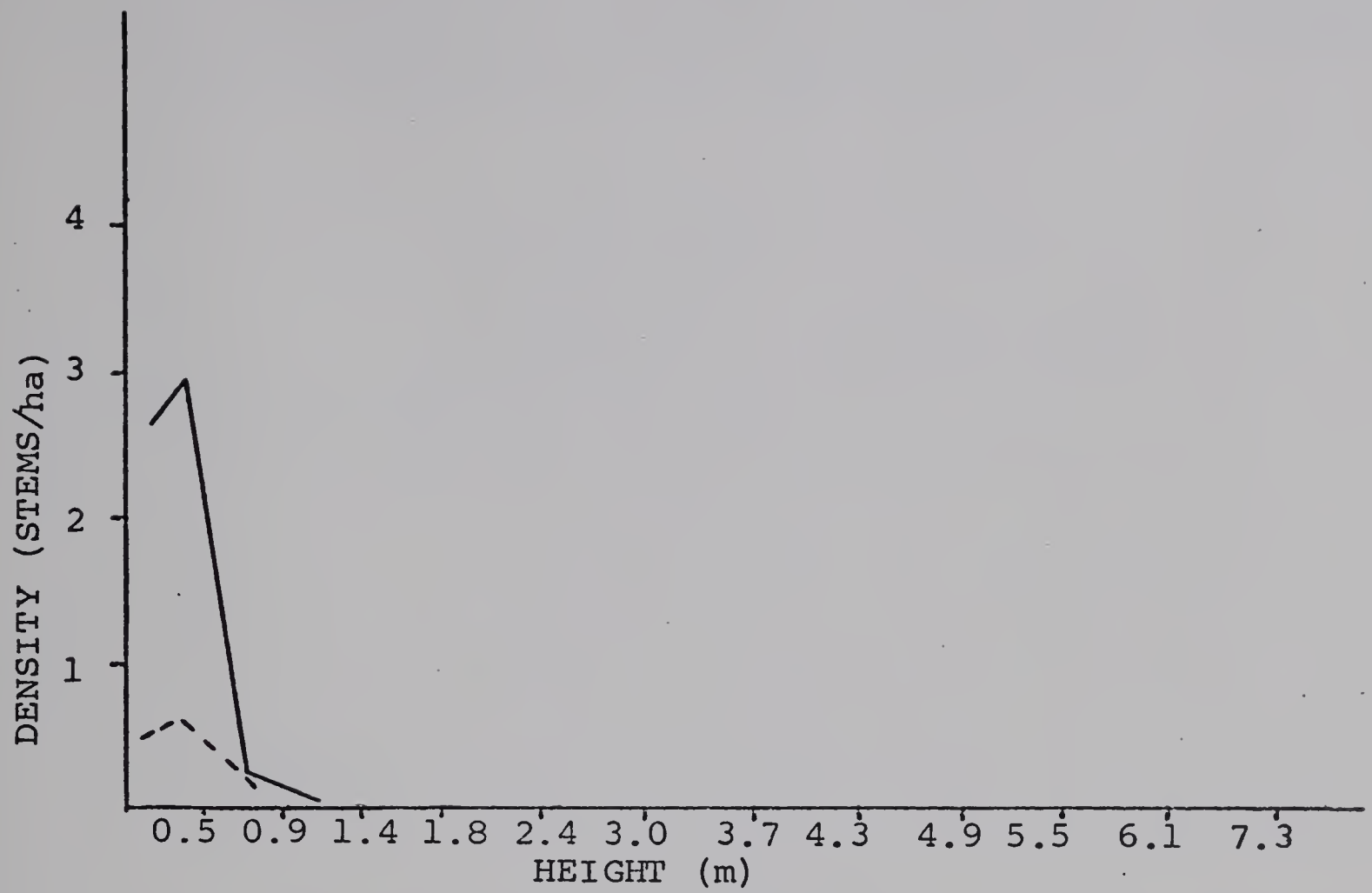


FIGURE 21. Height class distribution of pine (solid line) and aspen (dotted line) regeneration density in stand 21

Pine density - 4600 stems/ha

Aspen density - 800 stems/ha

Figures on vertical axis are thousands of stems/ha

FIGURE 22. Height class distribution of pine (solid line) and aspen (dotted line) regeneration biomass in stand 21

Pine biomass - 37 kg/ha

Aspen biomass - 25 kg/ha

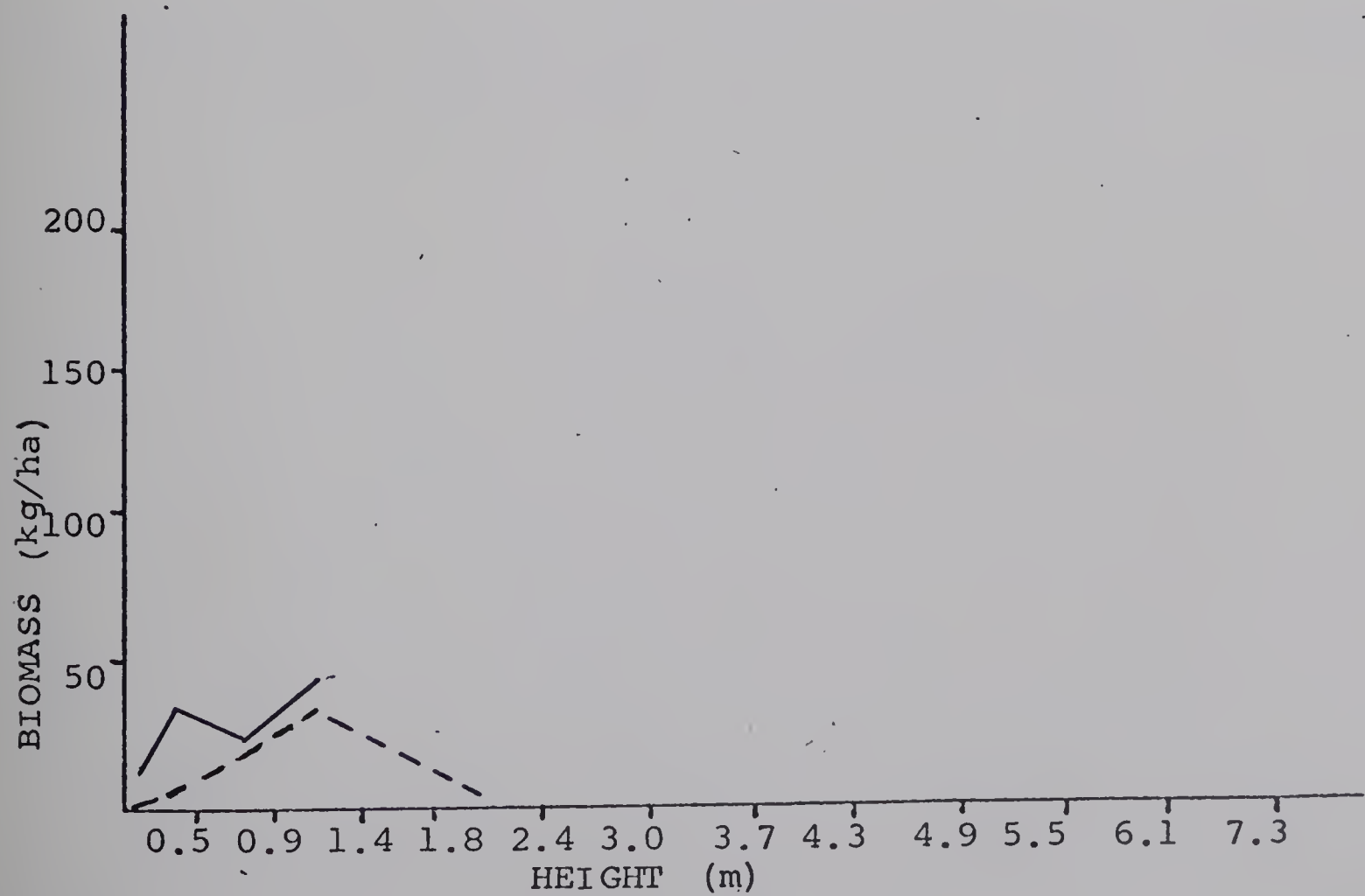
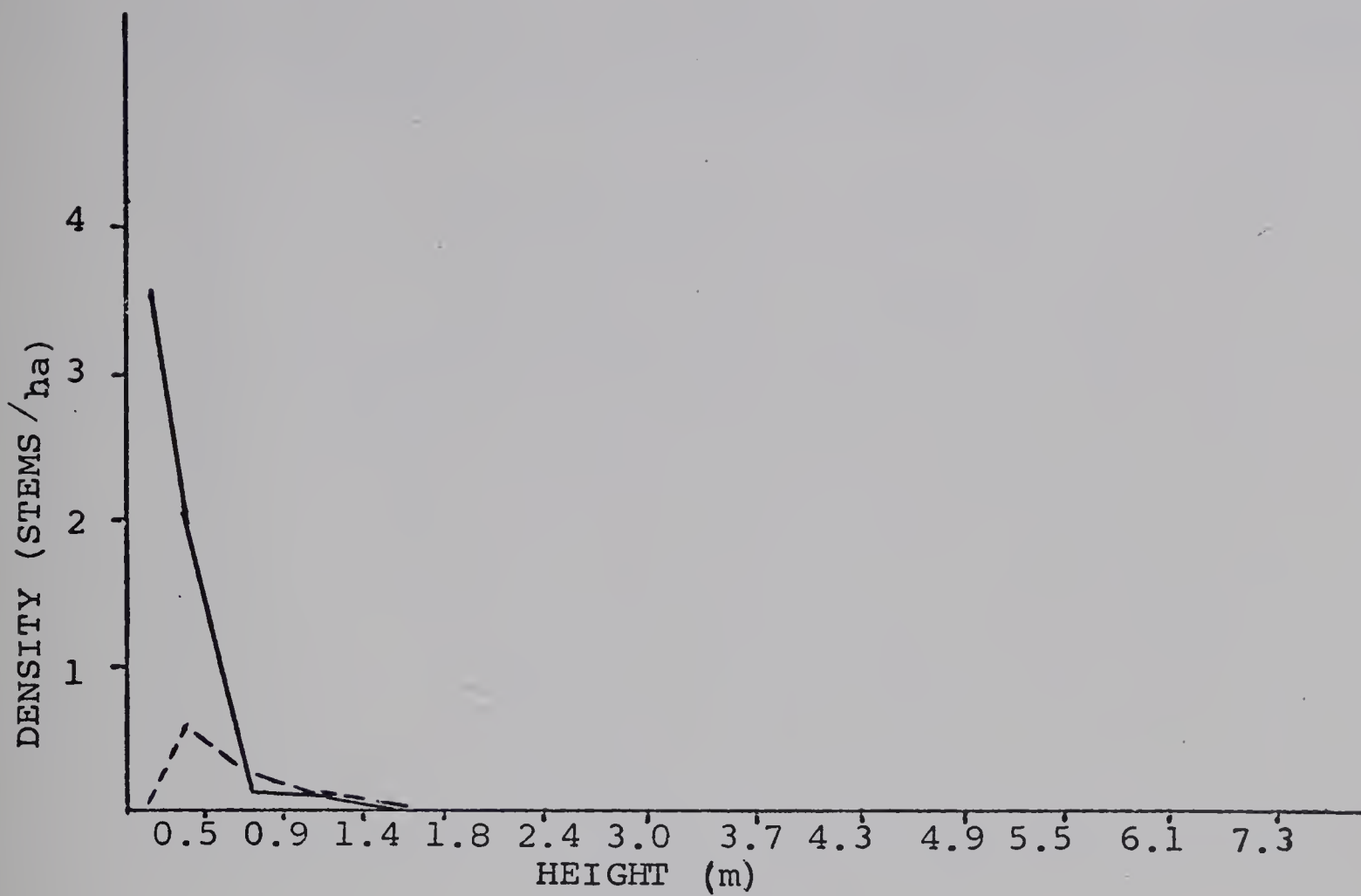


FIGURE 23. Height class distribution of pine (solid line) and aspen regeneration density in stand 23

Pine density - 11800 stems/ha

Aspen density - 13050 stems/ha

Figures on vertical axis are thousands of stems/ha

FIGURE 24. Height class distribution of pine (solid line) and aspen (dotted line) regeneration biomass in stand 23

Pine biomass - 72 kg/ha

Aspen biomass - 1800 kg/ha

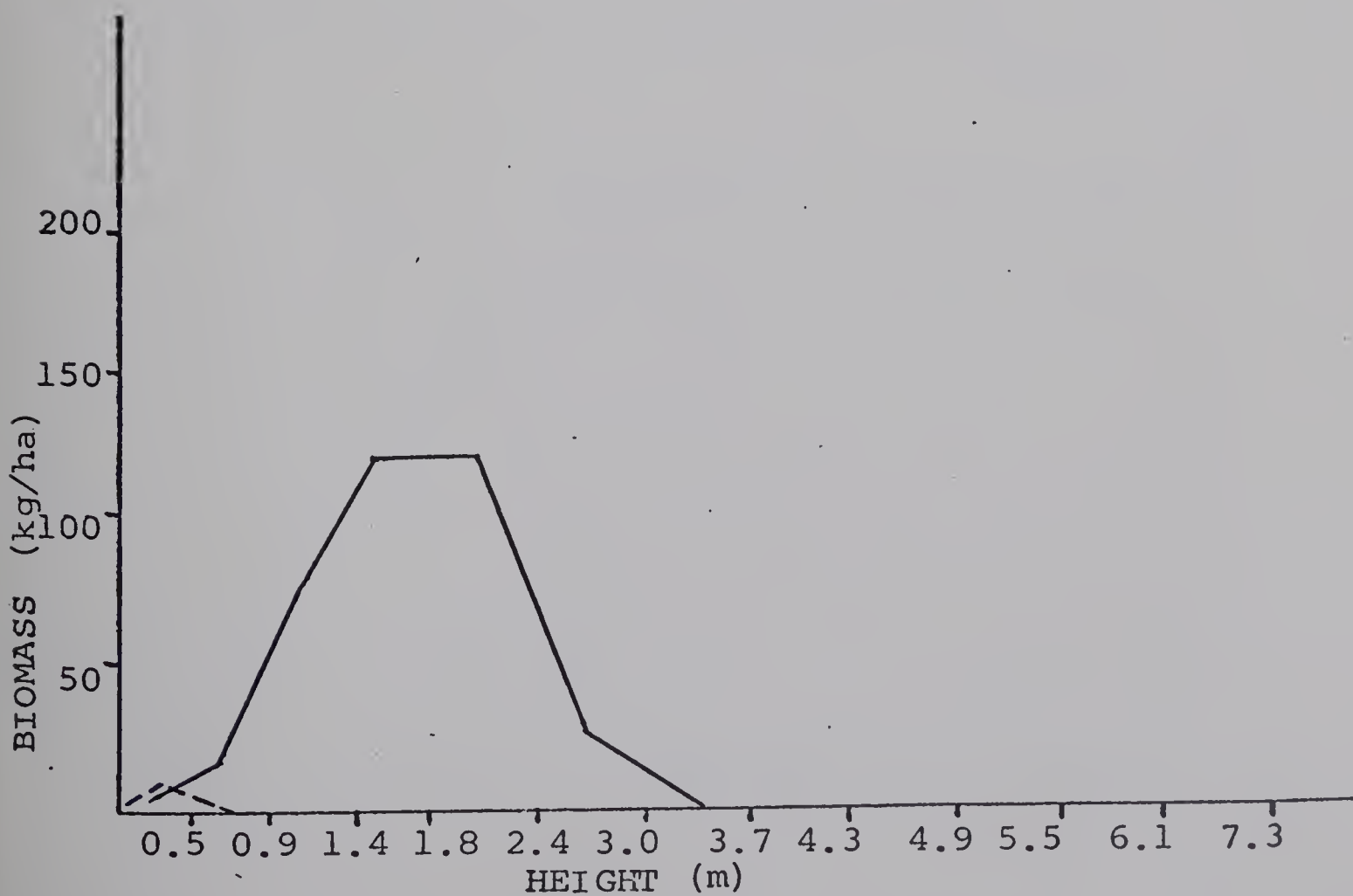
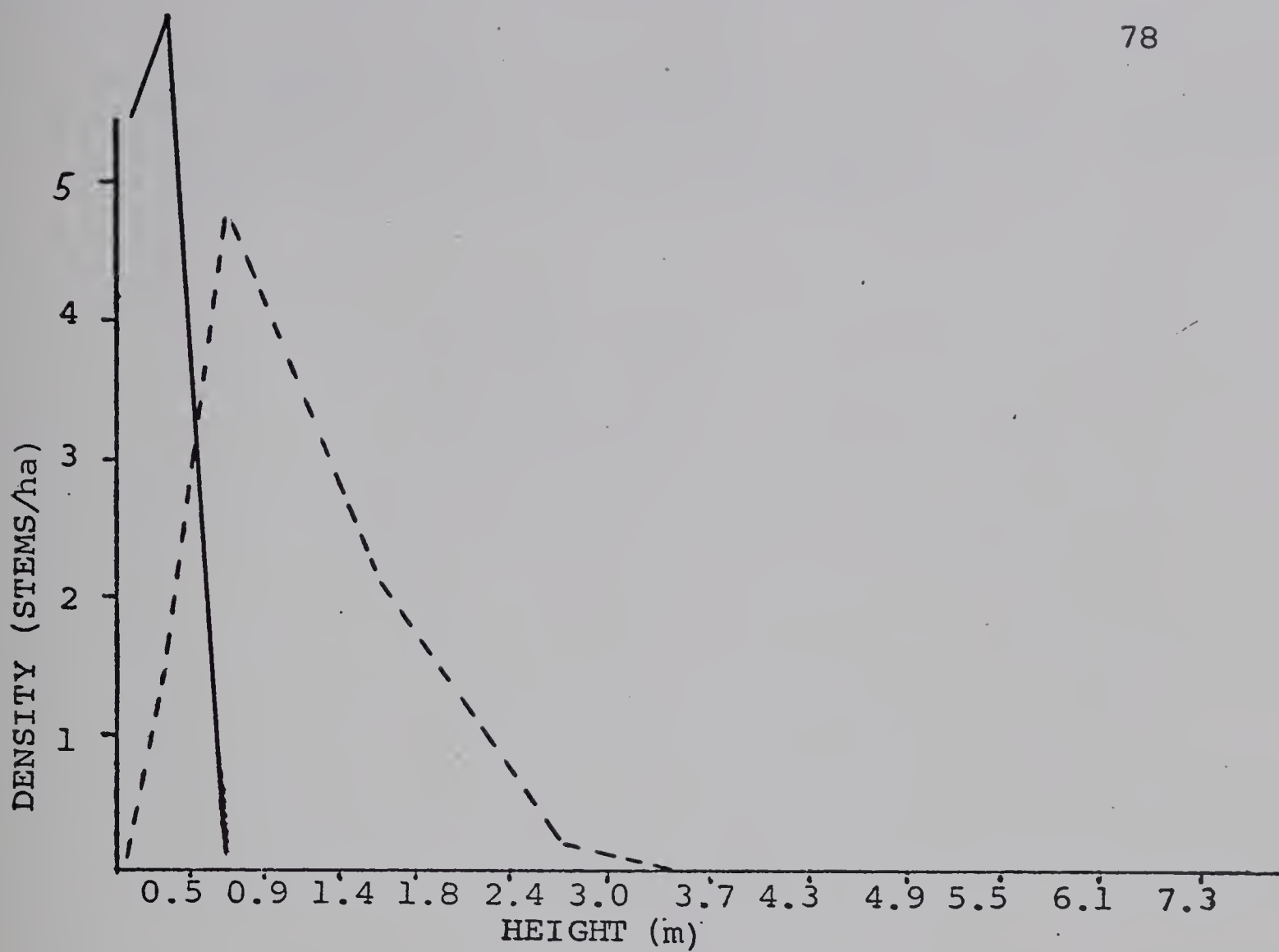


FIGURE 25. Height class distribution of pine (solid line) and aspen (dotted line) regeneration density in stand 1

Pine density - 16300 stems/ha

Aspen density - 2700 stems/ha

Figures on vertical axis are thousands of stems/ha

FIGURE 26. Height class distribution of pine (solid line) and aspen (dotted line) regeneration biomass in stand 1

Pine biomass - 4300 kg/ha

Aspen biomass - 460 kg/ha

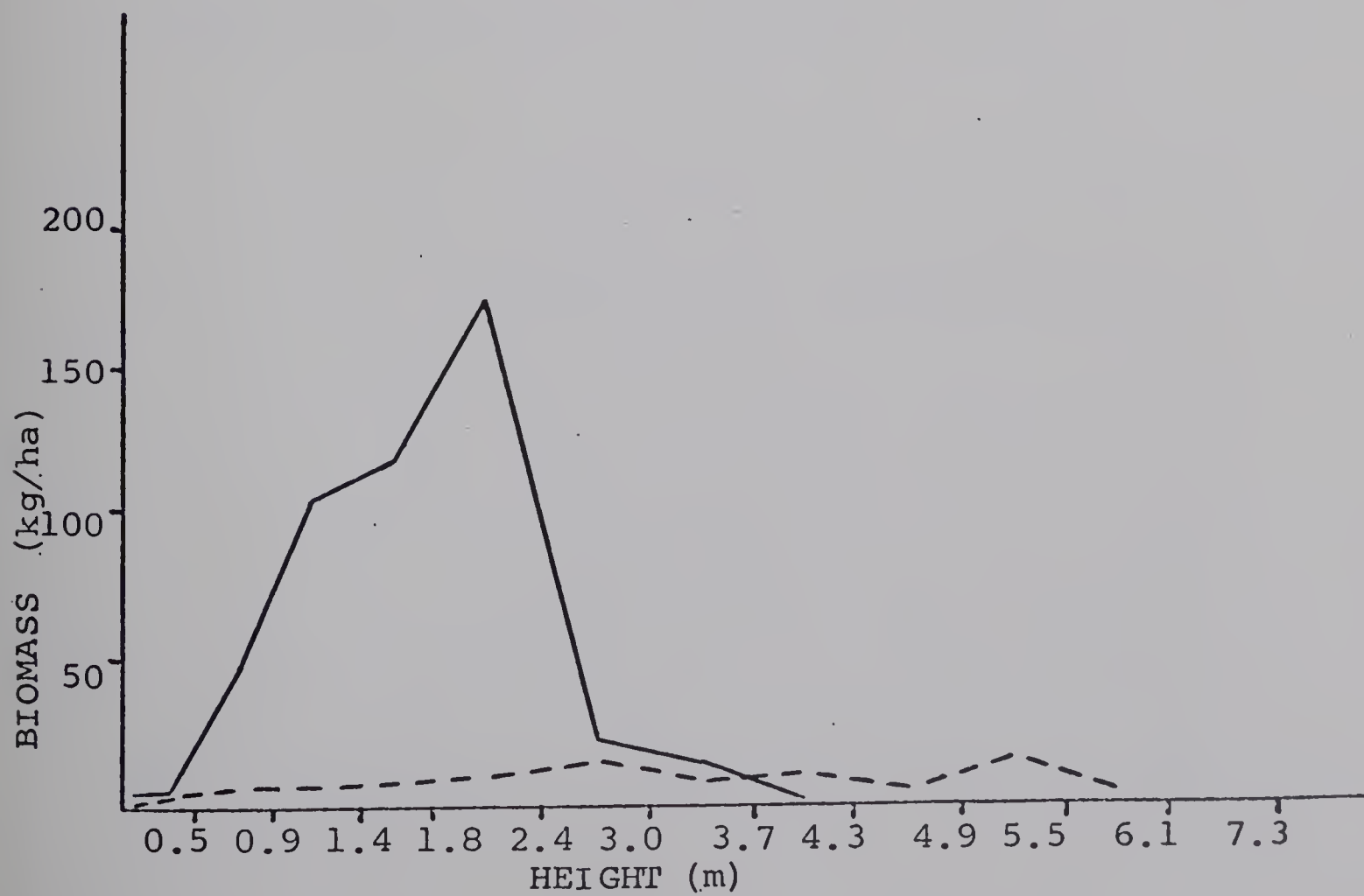
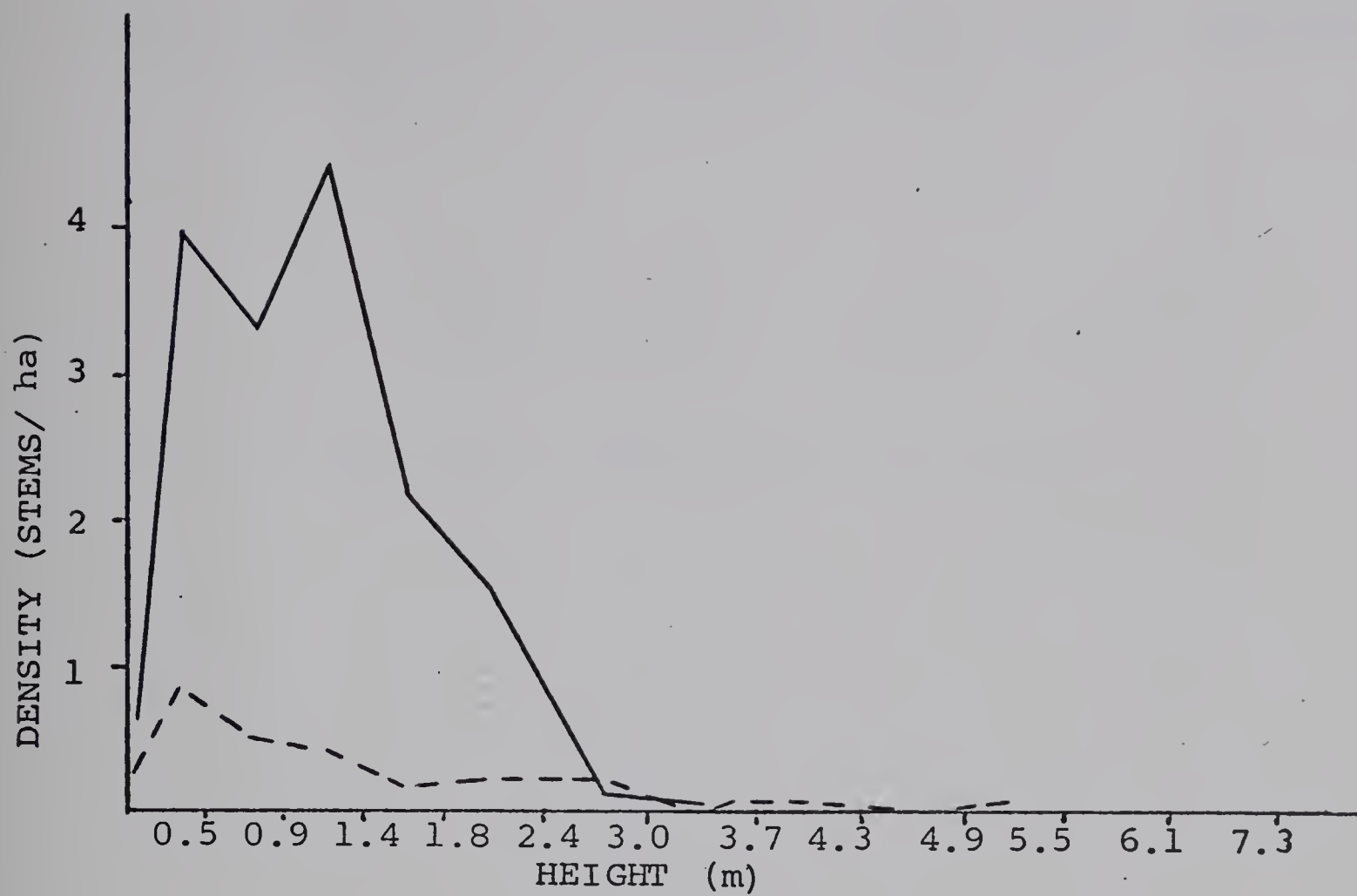


FIGURE 27. Height class distribution of pine (solid line) and aspen (dotted line) regeneration density in stand 4

Pine density - 19800 stems/ha

Aspen density - 4100 stems/ha

Figures on vertical axis are thousands of stems/ha

FIGURE 28. Height class distribution of pine (solid line) and aspen (dotted line) regeneration biomass in stand 4

Pine biomass - 4200 kg/ha

Aspen biomass - 1020 kg/ha

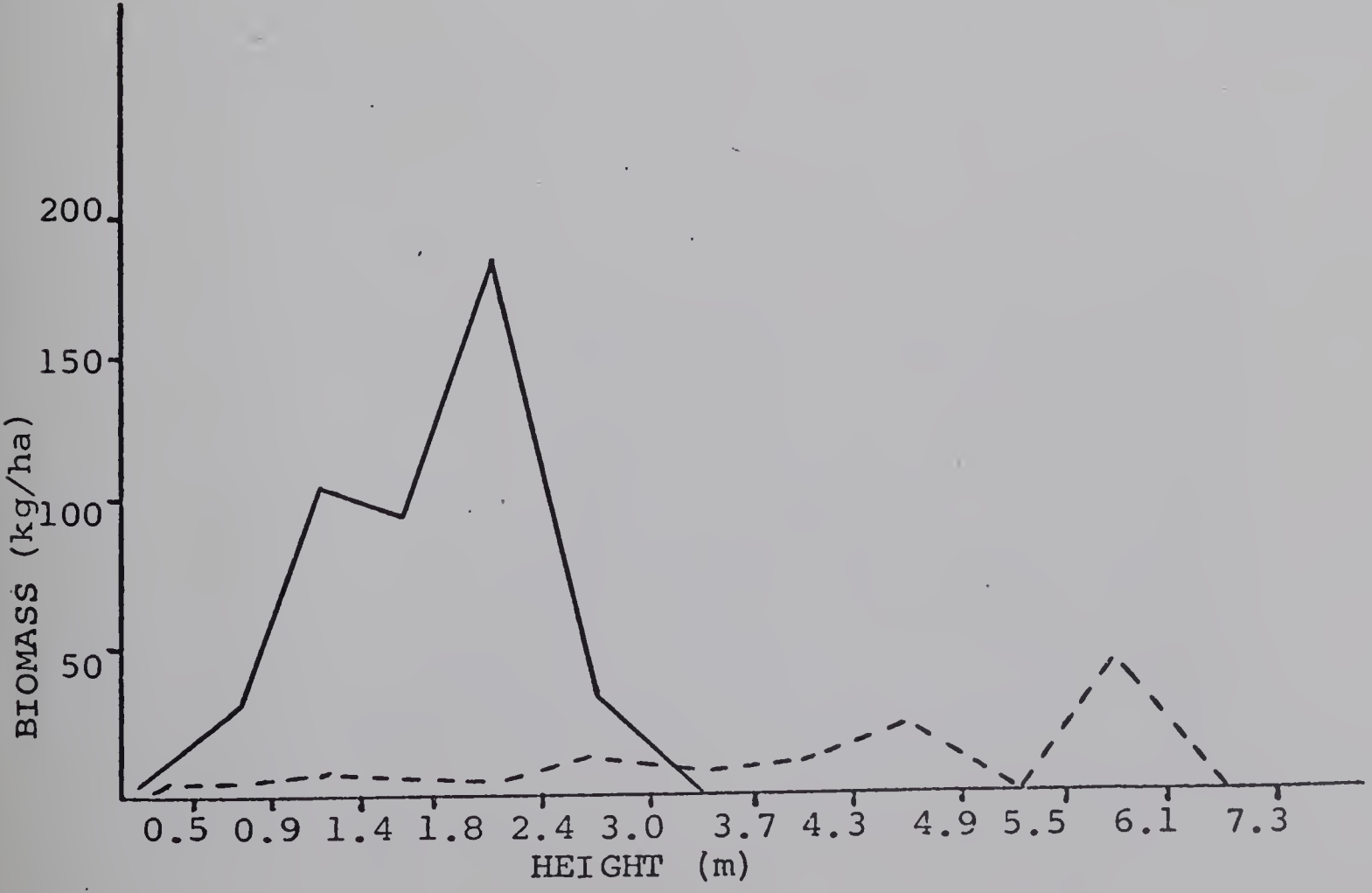
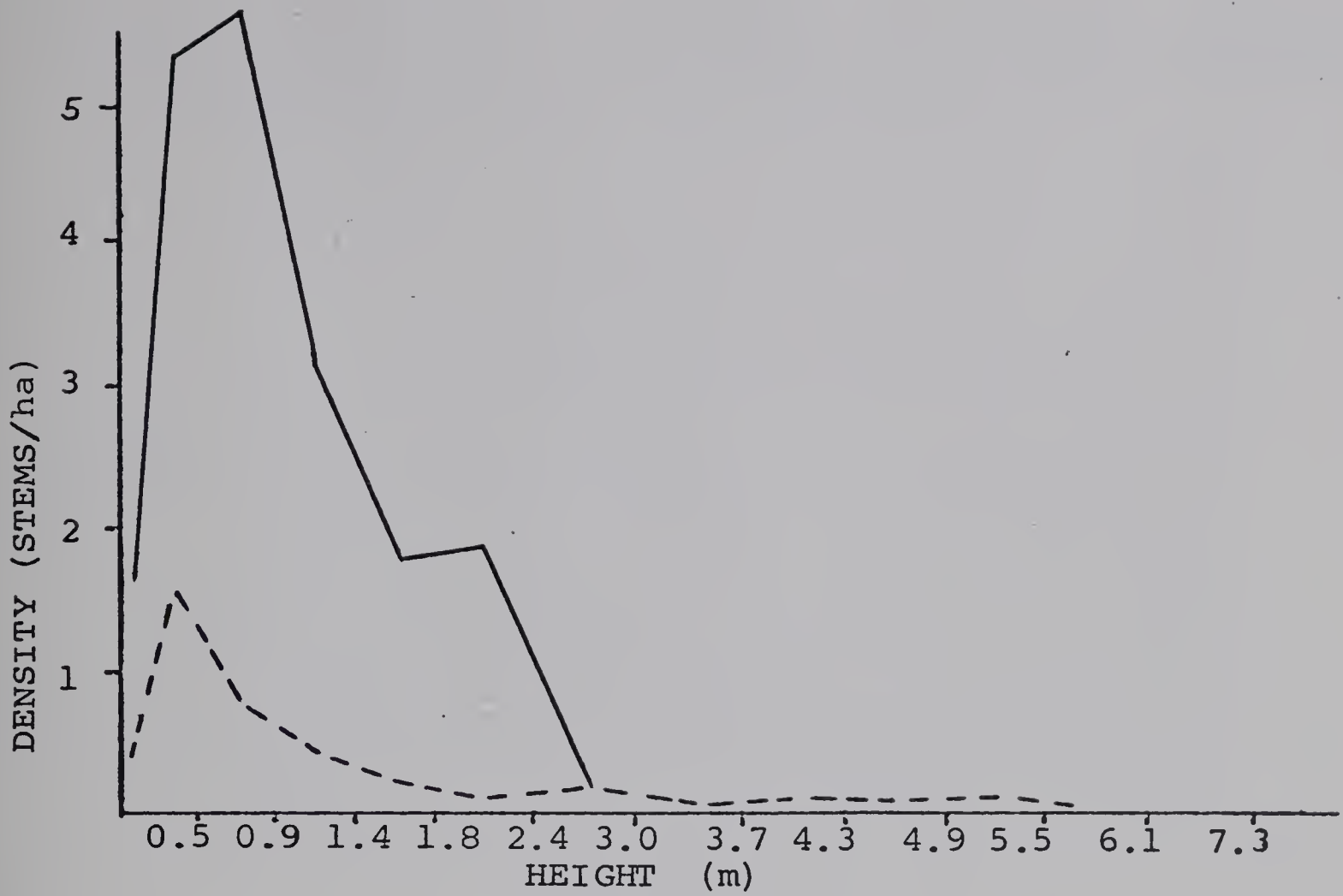


FIGURE 29. Height class distribution of pine (solid line) and aspen (dotted line) regeneration density in stand 3

Pine density - 5500 stems/ha

Aspen density - 8600 stems/ha

Figures on vertical axis are thousands of stems/ha

FIGURE 30. Height class distribution of pine (solid line) and aspen (dotted line) regeneration biomass in stand 3

Pine biomass - 1040 kg/ha

Aspen biomass - 6400 kg/ha

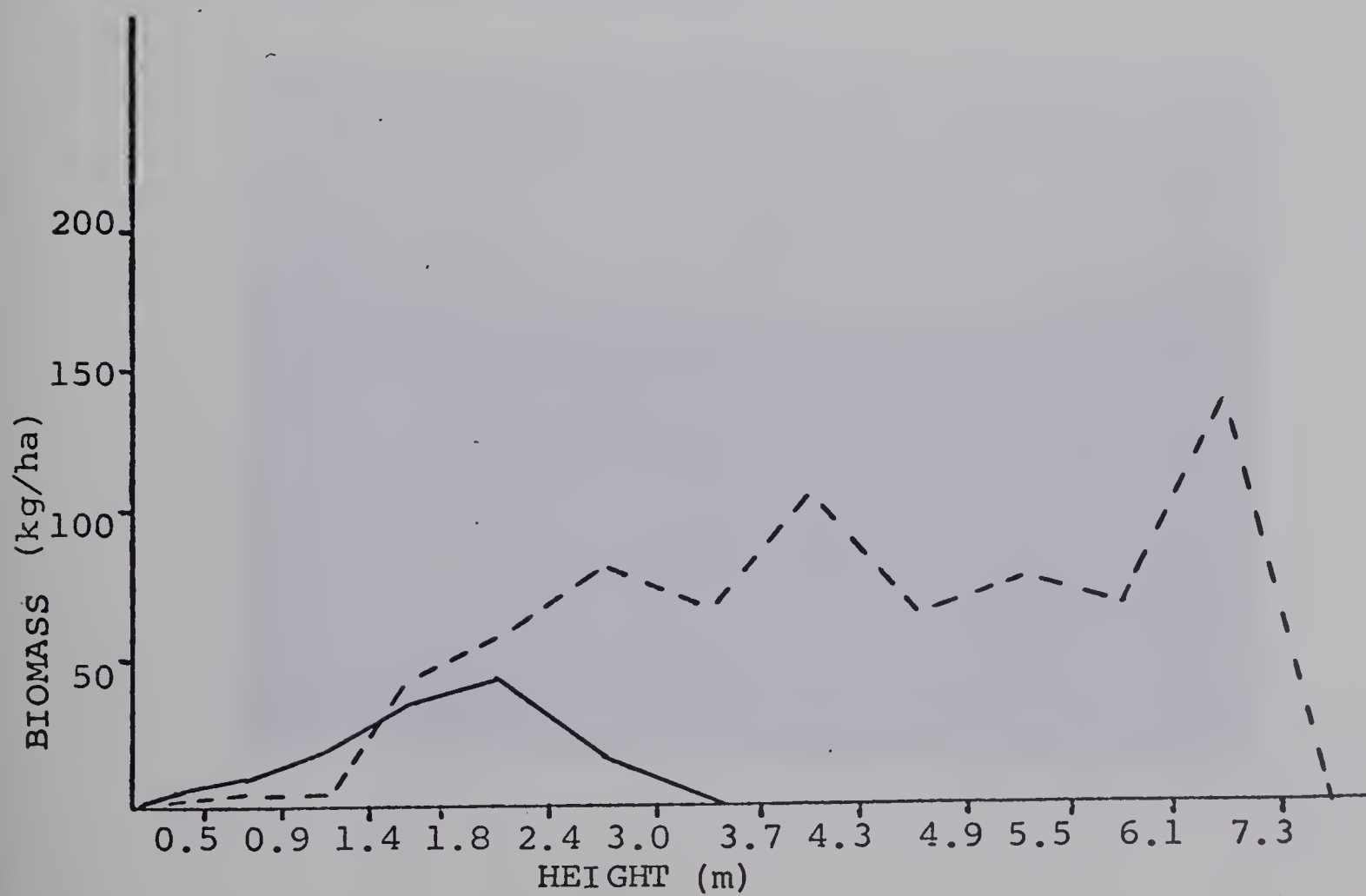
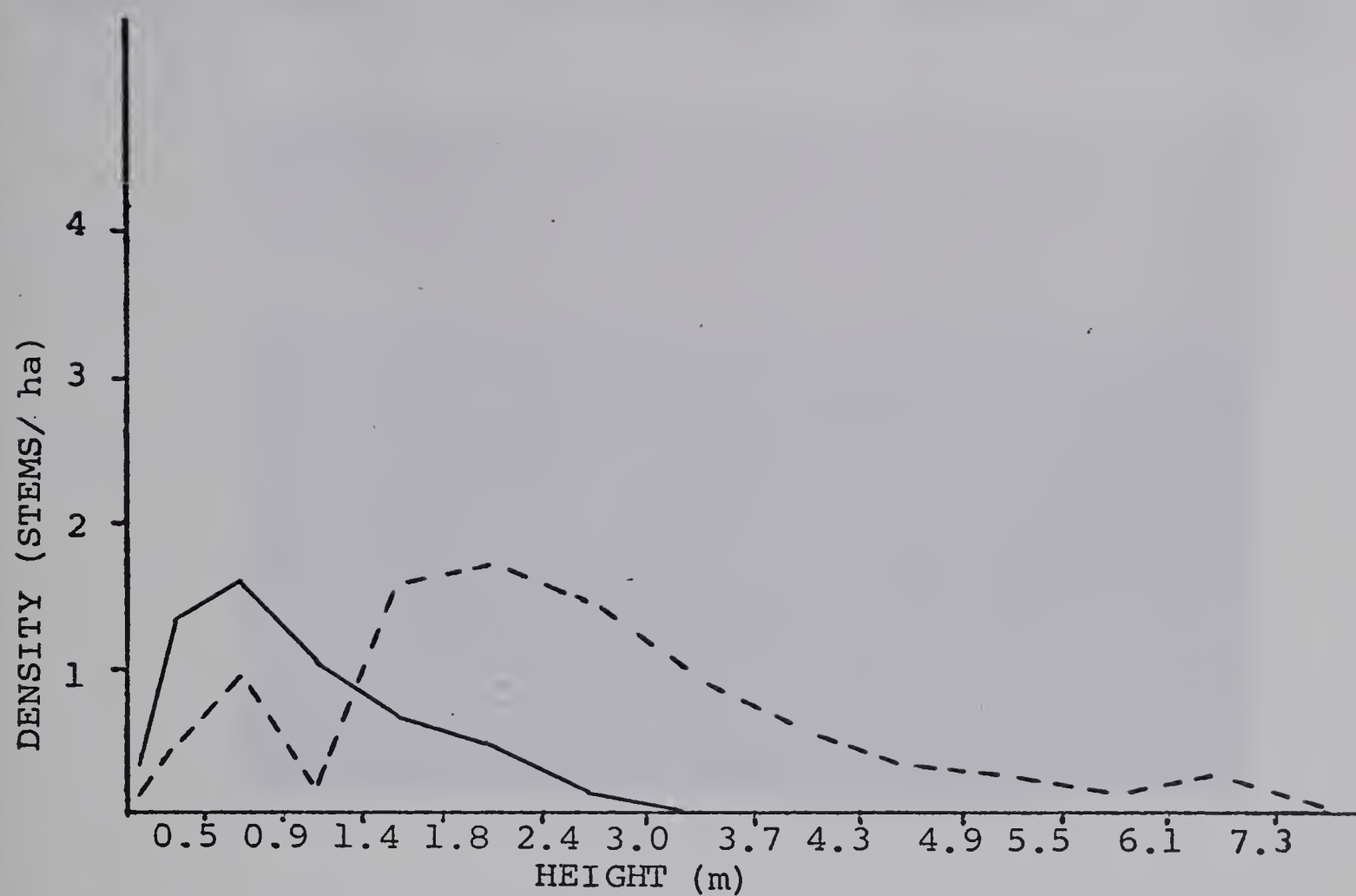




PLATE 1. Stand 24, a fairly typical 6 year old pine stand.



PLATE 2. Stand 23, illustrating dense aspen regeneration on a 6 year old stand.





aspen in the 6 and 12 year old stands (Fig. 18a-18d) show that the height growth of aspen is approximately twice that of pine on both the 6 and 12 year stands. Mean height growth per year for pine has tripled (0.13-0.38m) between 6 and 12 years after clearcutting. Height growth of aspen is slightly greater than that of pine for the same pine span (0.25-0.85m/year).

## ii. Density-Biomass Relationship

Tree regeneration is discussed mainly as it applies to the dominant tree species of the study area *Pinus contorta* and *Populus tremuloides*. Secondary consideration is given to the less important tree species *Populus balsamifera*, *Picea mariana*, *Picea glauca*, *Betula papyrifera* and *Abies lasiocarpa*. To satisfactorily describe the sampled range of variation in the height-class distributions of pine and aspen density and biomass, the six stands on which the height-age determinations were made are treated separately in the following discussion.

Stand 24 (Block 122) appears fairly typical of a 6 year old clearcut with respect to pine regeneration (Fig. 19) (Plate 1). The numbers of young pine are approximately equal in the 0-15 and 15-46cm height classes and very few pines are above 46cm, showing a very uniform rate of tree growth. Estimated pine density for this stand is 6200 stems/ha, lower



than the mean density for 6 year old pine stands (10,700 stems/ha).

Pine biomass on stand 24 is highest in the 15-46cm height class and for the total population is 60 kg/ha (Fig. 20).

Aspen is not common in stand 24. It shows a height-class density distribution similar to that of pine but its stand density of 1300 stems/ha is much below the mean of 4100 stems/ha for 6 year old stands. Aspen biomass is only 7 kg/ha.

Stand 21 (Block 70) is somewhat different (Fig. 21). Most of the pine is in the 0-15cm class although some pine has reached the 0.9 to 1.4m class. This taller pine is "residual," i.e., several years older than the regeneration established since clearing of the area. This was the only stand with residual pine regeneration. Pine density at 4600 stems/ha is about one-half the mean (10,700) for the 6 year old stands sampled.

Pine biomass is a very low 37 kg/ha, and is greatest in the 0.9-1.4m class which has the fewest individuals (Fig. 22), but the young trees soon make up in weight what they lack in number as the height/weight ratio decreases as the population ages.

Aspen density is 800 stems/ha in stand 21, much less



than that of pine and less than the mean (4100 stems/ha) for aspen in 6 year old stands.

Aspen biomass is 25 kg/ha and though low, is very close to that of pine in spite of its much lower density.

Stand 23 (Block 103) has experienced a rather dramatic increase of aspen of what was once nearly pure lodgepole pine forest.

Pine density (Fig. 23) is 11,800 stems/ha, close to the mean of 10,700 stems/ha. Two other 6 year old pine stands, 22 and 25 have even higher densities of 14,300 and 16,400 stems/ha respectively.

Pine biomass on stand 23 is low (72 kg/ha) due to the small size of the plants (Fig. 24).

Aspen density on stand 23 (Plate 2) is 13,050 stems/ha, not much greater than that of pine. While all pine regeneration in the stand is under 0.9m tall, with the modal class being 0.2-0.5m , the modal height class for aspen is 0.5 to 0.9m , with stems reaching 3.7 meters. Height and age counts (Fig. 18d) in this stand reveal that most of these taller young aspen trees originated after logging and are not residual.

Aspen biomass on stand 23 is 1800 kg/ha, nearly 25 times that of pine, reflecting the much faster initial growth



rate of aspen on this site. Biomass is greatest in the 1.4-2.4m classes.

Stand 23 appears to be progressing toward aspen domination, but the validity of this prediction depends upon how successfully the pine competes with the aspen in the future. This leads to a consideration of relative mortality in the two populations. Evidence of pine and aspen regeneration mortality within the stands discussed is negligible, and dead individuals constitute an insignificant proportion of the stands (Table 8). The apparently low pine and aspen mortality in young stands (less than 6 years) is probably due to the small size and inconspicuous nature of the individuals. Dead pine seedlings and aspen shoots soon become incorporated into the litter on the forest floor. Pine mortality is much greater during the early seedling stage than at any time afterward (Crossley 1956a). Aspen mortality during the first few years is probably not as great as that of pine due to the predominantly vegetative reproduction from root suckers originating from trees of the original forest. Aspen poplar may thus have a distinct competitive advantage in the early stages of secondary succession after clearcutting, if adult aspen trees were present in the pre-harvest stand.

An examination of three 12 year old stands will help to clarify the apparent trends in the dynamics of pine and



aspen tree regeneration.

Stand 1 (Block 2) shows minimal competition between pine and aspen (Fig. 25). Aspen is primarily restricted to distinct clones in low areas and some upland situations with local favorable soil texture-drainage characteristics. Aspen, though reaching heights up to 5.5m in the stand area, is still spreading and the modal height class is therefore only 0.2-0.5m. The stand density of 2700 stems/ha is low compared to the mean 12 year old stand density of 4800 stems/ha.

Aspen biomass in stand 1 is fairly evenly distributed throughout the population height classes but is greater in the upper classes (Fig. 26).

Pine regeneration density of 16,300 stems/ha in stand 1 shows a wider height class distribution than was evident in the 6 year old stands. This tendency is indicative of continuing pine establishment, most likely a result of seed from the adjacent forest as most of the slash borne seed has been released after 10 years (Crossley 1956b) and the 12 year old pines are not yet releasing seed. Differential height growth of the pines, as shown by the height-age samples (Fig. 18a), also accounts for the height variation of the pine population.

Pine biomass in stand 1 is greater in the taller



PLATE 3. Stand 3, pine and dense aspen in a 12 year old stand.



PLATE 4. Stand 4, uniform pine regeneration on a 12 year old stand.





height classes (Fig. 26). The modal biomass class is 1.8-2.4m in stand 1, as it is also in stands 3 and 4.

Stand 4 (Block 7) is very similar to stand 1 with respect to pine and aspen regeneration (Fig. 27) (Plate 3). Pine is distributed throughout the stand area whereas aspen tends to occur in the lower areas. The largest aspen on this block occur outside the stand area on a gentle slope with a S E aspect. Pine and aspen density biomass show frequency distributions very similar to those of stand 1. Pine biomass of 4200 kg/ha, in stand 4, is very close to that in stand 1, but aspen biomass of 1020 kg/ha is more than double the 500 kg/ha of stand 1 (Fig. 28).

Stand 3 (Block 6) is distinctly different from stands 1 and 4 with respect to the abundance and size class distributions of pine and aspen regeneration (Fig. 29) (Plate 4). Both pine and aspen tend to be more abundant in the upper height classes than in stands 1 and 4, although density of both species is again concentrated in the lower height classes. The outstanding feature of this stand is the obvious dominance of aspen. The taller and more numerous aspen overshadow the pine making them less conspicuous. The pine density of 5500 stems/ha is lowest of five 12 year stands. Aspen density, however, is 8600 stems/ha and greater than in any of the other 12 year old stands, and



nearly twice the mean of 4800 stems/ha for stands of that age.

The dominance of aspen in stand 3 becomes even more obvious when the biomass height class distributions for pine and aspen (Fig. 30) are compared. Aspen though less than twice as numerous as pine has more than six times as much biomass.

By the twelfth year after clearcutting, the growth rate of aspen appeared to have slowed down relative to that of pine. This is suggested by the fact that ratio of the mean weights of individual pine/aspen was 0.14 on the 6 year old stand versus 0.57 on the 12 year old stands. More intensive research relative to such ratios might lead to instructive predictions of the length of time required for the possibility of individual pine overtaking aspen in the successional sequence. This could have potentially important bearing on forest management practice.

#### Other Stands

The foregoing discussion dealt primarily with tree density and biomass on 6 stands of the age extremes sampled. Regeneration densities for all tree species in the stands are presented in Table 8.

It is perhaps desirable though at this point to con-



TABLE 8. HEIGHT CLASS DISTRIBUTION OF REGENERATING TREE POPULATIONS ON 25 CLEARCUT STANDS\*

A. <i>Pinus contorta</i>		Height class midpoints (m)										Total
Block	Stand	0.08	0.31	0.69	1.14	1.60	2.14	2.75	3.36	3.47		
2	1	L	7±2	40±6	34±5	45±3	22±1	15±1	1±1	T	163	
5	2	D	7±3	33±9	4±1	3±1	T				7	
6	3	L	3±2	13±3	16±5	10±4	7±2	5±1	1±1		81	
		D			20±7	12±4	7±3	2±1				
7	4	L	16±5	54±11	57±11	32±5	18±5	19±8	2±1		55	
		D	7±3	19±4	21±6	12±4	T				1	
9	5	L				3±1	3±1				198	
		D				T					4	
		L					3±1	T			62	
		D										
1N	6	L	16±4	61±9	59±9	26±6	10±4	1±1			174	
		D			T	1±1					1	
2N	7	L	11±5	116±29	98±23	23±7	3±2				251	
		D		1±1	1±1						2	
8N	8	L	20±6	110±22	110±18	41±9	2±1				284	
		D		1±1	1±1						2	
11	9	L	9±3	51±11	43±11	18±5	1±1				123	
		D		T	T	T						
12	10	L	5±2	19±5	28±5	11±3	8±2	1±1			71	
		D			T							
10N	11	L	24±9	51±19	18±6	3±2	T	T			97	
		D			T							
22	12	L	4±2	10±4	6±1	T					20	
		D										
28	13	L	10±5	24±6	18±5	8±4	T				62	
		D									91	
32	14	L	62±13	120±17	23±5	1±1					206	
		D										
9N	15	L	19±8	84±20	27±5	4±2					135	
		D			T							



TABLE 8. Cont'd.

A. <i>Pinus contorta</i>		Height class midpoints (m)									Total
Block	Stand	0.08	0.31	0.69	1.14	1.60	2.14	2.75	3.36	3.47	
60	16	L	75±9	67±12	2±1						144
		D		T							
68	17	L	42±12	65±19	4±2						110
		D	T	T							
114	18	L	21±4	30±5	3±1	1±1					55
		D									
116	19	L	2±1	3±1	T						6
		D		T							
121	20	L	35±7	42±12	8±3						85
		D	T								
71	21	L	28±5	16±3	1±1	1±1					46
		D	T								
102	22	L	64±11	78±17	1±1						143
		D		2±2							
102	23	L	55±11	63±16	1±1						118
		D									
122	24	L	28±9	31±8	3±1	T					62
		D	T								
123	25	L	101±39	62±20							164
		D	T	T							







TABLE 8. Cont'd.

[illegible]



TABLE 8. Cont'd.

[illegible]







TABLE 8. Cont'd.

D. <i>Picea mariana</i> + <i>glauca</i>		Height class midpoints (m)					E. <i>Abies lasiocarpa</i>					
Block	Stand	0.08	0.31	0.69	1.14	1.60	Total	0.08	0.31	0.69	1.14	Total
2	1	1±1	2±1				3					T
5	2	2±1	2±1				3					
6	3	T				T	1					
7	4	8±6	3±1	1±1	T		13					
99	5	1±1	T			T	2					
1N	6	3±1	1±1				4	T				
2N	7	1±1	1±1				1					
8N	8											
11	9	3±2	4±2	T			11					
12	10	8±5	7±3				15					
10N	11	5±2	2±2	4±3			11					
22	12	T	1±1				1					
28	13	5±2	1±1	T			7					
32	14	11±3	T				11					
9N	15	3±1					3					
60	16	23±12	1±1	T	T		25					
68	17	8±3					8					
114	18	4±1	1±1				5	1±1		T		1
116	19	2±1	T				2					
121	20	9±3	1±1				10	6±2	T			6
71	21											
102	22	1±1					1					
103	23		T									
122	24	7±3		1±1	8±4		16					
123	25	18±16	3±2				21					



TABLE 8. Cont'd.

F. <i>Betula papyrifera</i>		Height classes (m)							
Block	Stand	0.08	0.31	0.69	1.14	1.60	2.14	2.75	Total
22	12	L	1±1	7±3	16±7	6±3	7±4	1±1	38
		D							
32	14	L	T						
		D							
60	16	L	1±1	2±2					3
		D							
121	20	L	T	T					
		D							
122	24	L	T	T					
		D							

\* - Density data ± standard error are in 100's of stems per hectare  
 "T" - trace, i.e. <50/ha  
 L - living  
 D - dead



sider stands with high and low extremes of pine and aspen density and some of the factors accounting for these extremes.

Pine density was greatest in stands 7 and 8 (Table 8) which had 25,100 and 28,400 stems/ha respectively. These stands, cleared in 1960-61, are very similar and are only 1 km apart. The soils appear dry and well-drained. This condition is indicated by the absence of *Calamagrostis canadensis* on stand 8 and cover of less than 0.5% on stand 7. *Carex aenea*, the most common sedge of the study area, is absent from stands 7, 8 and 14, the latter having the third highest pine density of 20,600 stems/ha. *Carex aenea* occurred in all other stands and had a cover of 1% in five of these. Balsam poplar was absent from the quadrats in both stands 7 and 8, and was sparse in the transect tally. This is true also of stands 5, 14, and 23 which have high pine densities, and of stand 19 which had the lowest pine density and was a very moist site. Aspen density of stands 7 and 8 is 2700 and 3800 stems/ha respectively and is slightly below the mean of 5800 stems/ha for stands cleared during 1960-61.

Pine height class distributions in stands 7 and 8 (Table 8) are similar, with the majority of trees in the 0.2 to 0.9m classes and no individuals above 1.8m.



The height-class distributions for aspen in stands 7 and 8 (Table 8) are also similar to each other, and more uniform than that of pine, with no individuals greater than 3m tall.

With respect to features other than those described above, stands 7 and 8 are very similar to other high-medium density stands of the area.

In contrast to stands 7 and 8, stands 12 and 19 (Table 8) cleared during 1961-62 and 1963-64 respectively, have the lowest pine density estimates of 2000 and 600 stems/ha respectively. These stands are, however, very different in other respects, as confirmed by their mutual remoteness on the ordination (p. 62 ). Stand 12 is distinct from the other stands in several respects — higher altitude (1157m ), coarser textured soil, and distinctive vegetation set it apart from the other stands. It had the third highest cover of *Epilobium angustifolium* (13%) after stands 22 (20%) and 19 (18%). Stand 12 was the only stand in which *Aster ciliolatus* was absent. *Aralia nudicaulis* had a cover of 4% in stand 12 and occurred only in 4 other stands with a cover of 1% or less. *Gymnocarpium dryopteris*, the oak fern, had a cover of 1% and was present in only two other stands, 19 and 3, both of which also had fairly low pine densities (Table 8). *Spiraea lucida* had a cover of 1% in stand 12



occurring in 50% of the quadrats. The only other occurrence of this species was in stand 3. *Galium triflorum* occurred only in stands 12 and 19, with cover of less than 0.5%. Species occurring only in stand 12 include *Smilacina stellata*, *Actaea rubra*, *Dryopteris spinulosa* and *Betula papyrifera* (Table 4). Many of the birch trees in stand 12 were 2m tall and there was evidence in the form of old logs, of birch having been present before logging. Alder on stand 12 was very dense and nearly impenetrable. This stand was the only one which possessed birch and alder in abundance. The dense shrub cover in this stand provides good habitat for ungulates which have browsed the leaders off greater than 60% of the pines.

Most of the pine regeneration in stand 12 (Table 8) is in the 0.2-0.5m height class, and none is taller than 1.4m. Aspen is fairly evenly distributed through the height classes (Table 8) with some trees 3m tall.

Stand 19 had the lowest pine regeneration density of any of the stands sampled and had floristic affinities to stand 12 as noted above. However, it had much finer, more poorly drained soil and appeared to be much moister, though *Calamagrostis canadensis*, a grass found on moist sites, has only 3% more cover than on stand 12. Quadrat frequency of this species in stands 12 and 19 is 80% and 90% respectively. *Vaccinium myrtilloides* had a cover value of less than 1% on



only 3 stands: 2, 12, and 19. *Petasites palmatus*, *Epilobium angustifolium*, *Rubus pubescens*, *Viburnum edule*, *Equisetum arvense* + *E. sylvaticum* and *Mertensia paniculata* attain their maximum cover values in stand 19 (Table 4). The abundance of the species mentioned above may serve as an indicator of site quality with respect to tree natality though the correlations of the cover of these species with tree regeneration density are however, not significant on a stand basis.

Stand 19 also had the lowest aspen density (250 stems/ha) of any of the stands. The height-class distributions of pine and aspen (Table 8) indicate the lack of vigor of the populations of these species. No pine or aspen taller than 0.9m occur within the stand.

Stands with extremes of aspen regeneration will now be discussed with reference to distinctive stand attributes. Aspen density is highest in stands 23 (Fig. 23), discussed in the section on biomass, and in stand 9 (Table 8) (cleared 1960-61). Stands 23 and 9 do not have any particularly distinctive floristic attributes (Tables 4,5) and, in fact, are quite dissimilar with respect to floristic composition as shown by the ordination (Fig. 10). They are, however, similar in at least two respects: coarse soil texture (Fig. 12b) and the highest soil potassium (over 325ppm.) in the Ae horizon (Fig. 16).



The height class distribution of pine in stand 9 (Table 8) is similar to that of stands previously discussed and to other stands cleared during 1960-61 (Table 8). The height class distribution of the aspen population in stand 9 however appears to be skewed much more towards the lower classes than in other stands. Although some aspen up to 4.3m, tall occur, over half is less than 0.5m tall. indicating that much of the aspen population probably did not originate the summer following the cutting operation, but several years afterwards and that they are probably still spreading. This condition is also characteristic of stands 4, 6, 7, and 10 which were cleared before or during the same year as stand 9 as well as in stands 11, 14, 16, 17, 20, 21 and 24 which were cleared during 1961-62 or later (Table 8).

Aspen density is lowest in stand 19 (Table 8) as discussed previously, and in stand 16 (Table 8). The aspen density of 800 stems/ha in stand 16 is fairly evenly distributed throughout the size classes, with no individuals taller than 1.8m occurring in the stand area. Stand 16 has no strong floristic differences from other stands (Tables 4, 5). Stand 16 is most similar to stand 9 as shown by the ordination (Fig. 10), but stand 9 had a much higher aspen density than stand 16.

#### Pine and Aspen Mortality

A discussion of the height-class-density distributions



of the pine and aspen populations is not complete without a consideration of the role of mortality.

Pine and aspen mortality is more evident on the 12 than on the 6 year old stands, but has not yet caused appreciable thinning in them. The apparent tendency of pine and aspen density to increase up to 9-10 years then decline (Figs. 31, 32) is thought due to differences between sites rather than an age effect. Pine and aspen mortality is, however, greatest in the 11-12 year stands (Figs. 31, 32). This increase is significant at the 5% level when an analysis of variance test between years is done. Duncan's Multiple Range Test indicates years 9-12 are significantly different from the other years (Table 6).

Analysis of variance and Duncan's Multiple Range Test do not yield significant difference among and between years with respect to living pine and aspen density. This is due in part to the wide range of stem densities of stands cleared within any one year. Differences between sites obscure age related effects.

Crossley (1956a) observed that most of the pine regeneration became established on the first year on a dry clearcut near Strachan in the Alberta foothills. He stated that germination would probably continue for several years but just keep pace with mortality which is high during the

FIGURE 31. Lodgepole pine regeneration density (solid line)  
from 5-12 years after clearcutting

Means  $\pm$  standard errors for each year are given.

n = 5

Mortality shown by dotted line

Figures on vertical axis are thousands of stems/ha

FIGURE 32. Aspen regeneration density (solid line) from  
5-12 years after clearcutting

Means  $\pm$  standard errors for each year are given.

n = 5

Mortality shown by dotted line

Figures on vertical axis are thousands of stems/ha

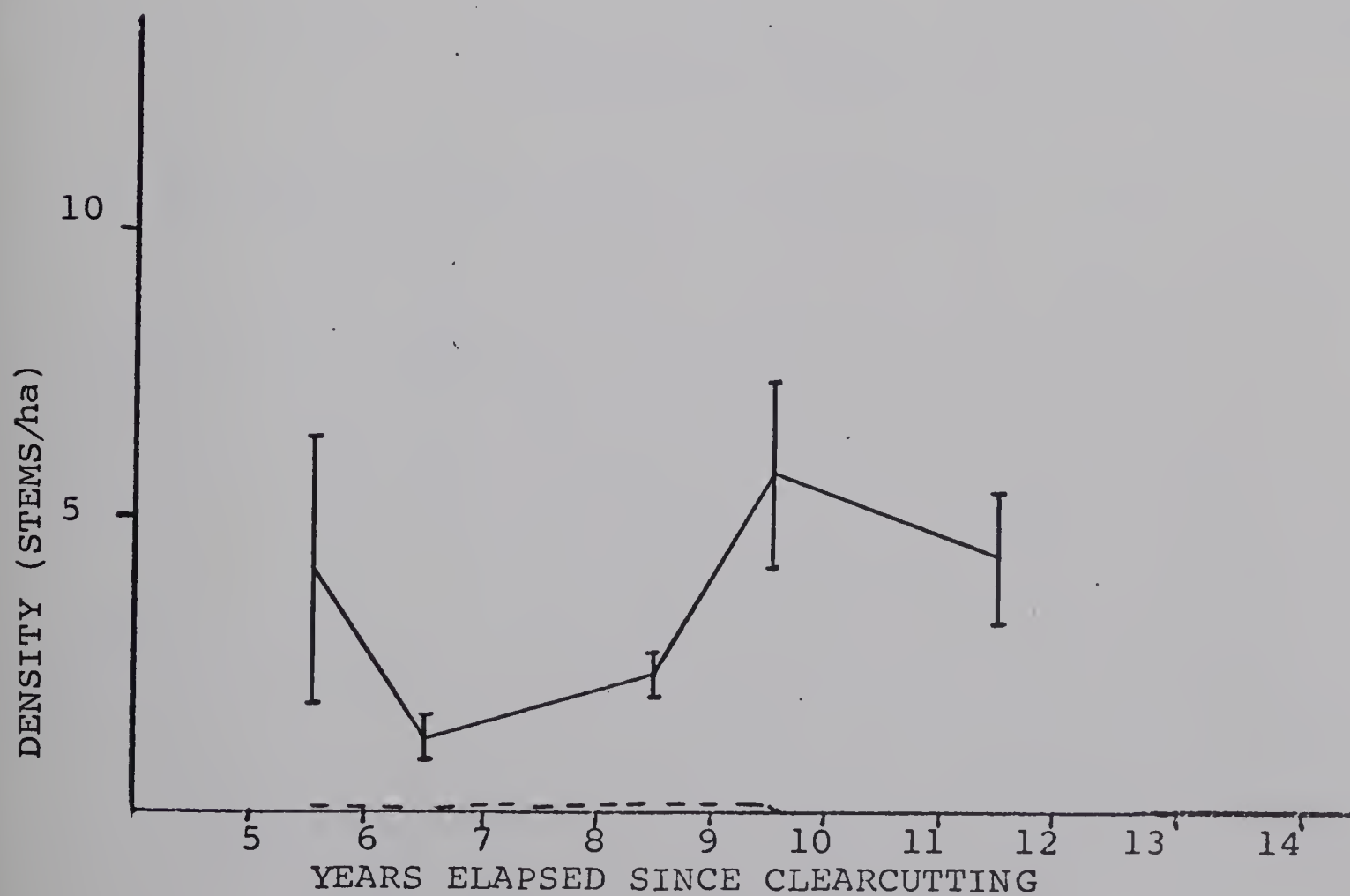
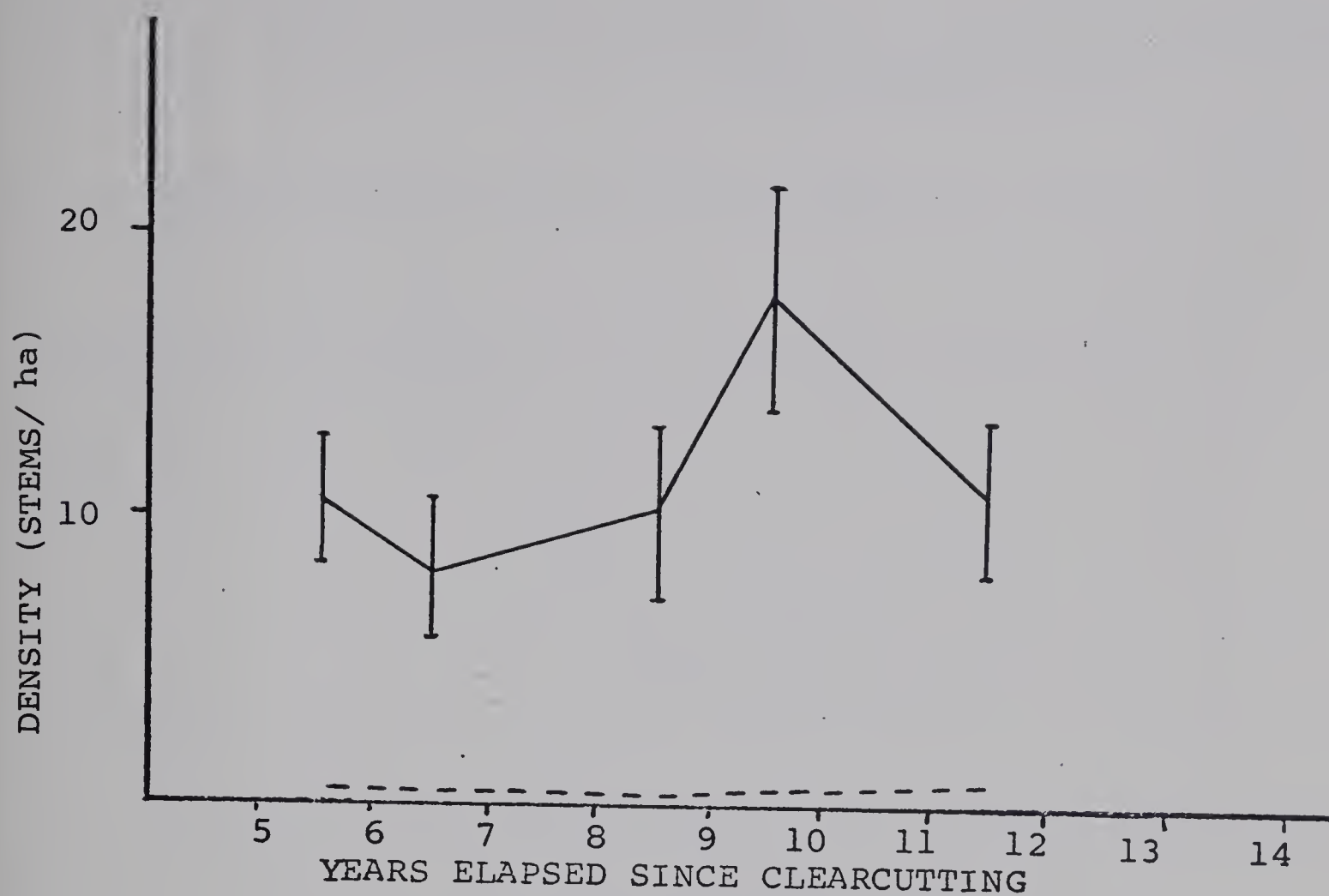


FIGURE 33. Balsam poplar regeneration density from 5-12 years after clearcutting

Means  $\pm$  standard error for each year are given.

n = 5

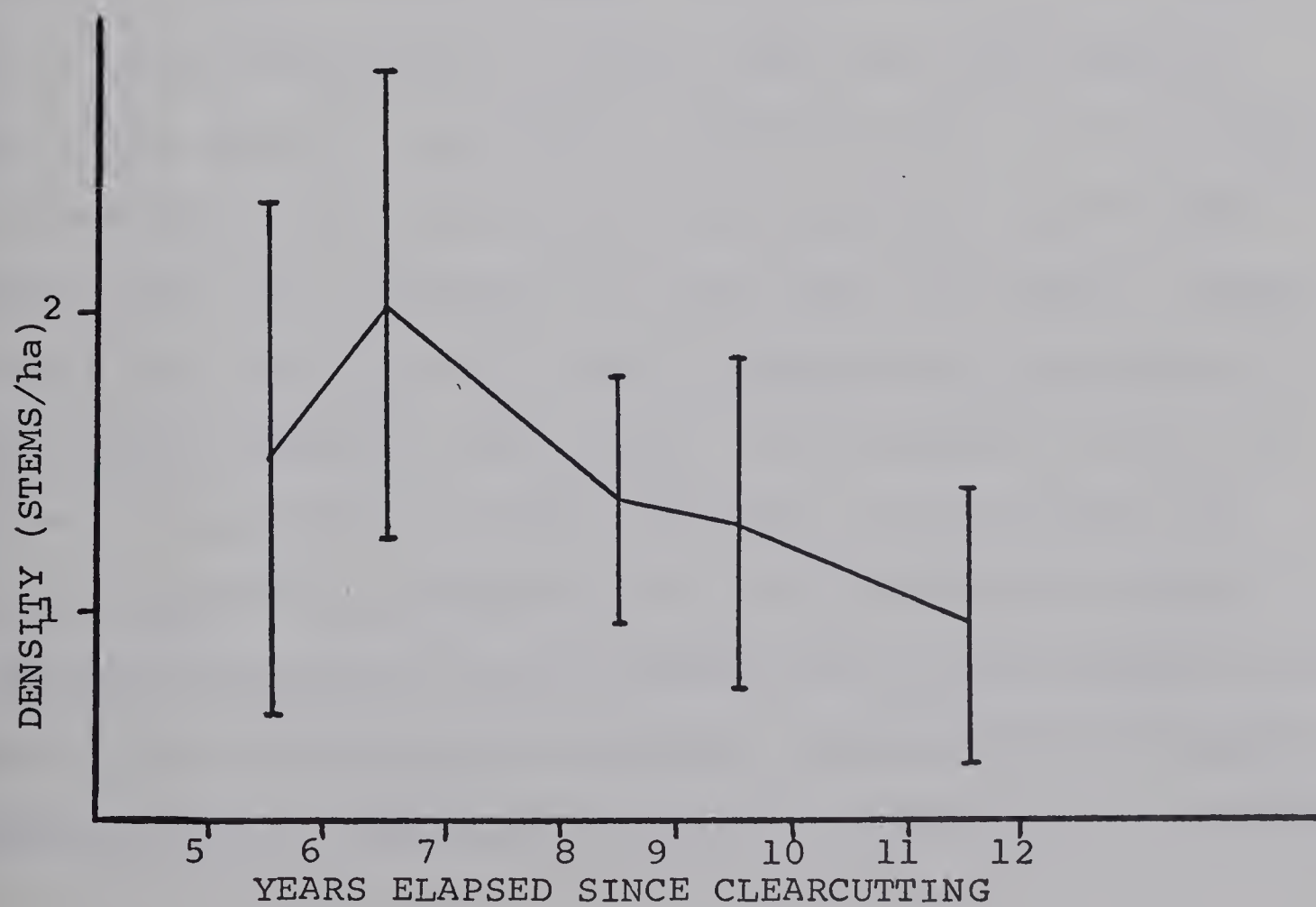
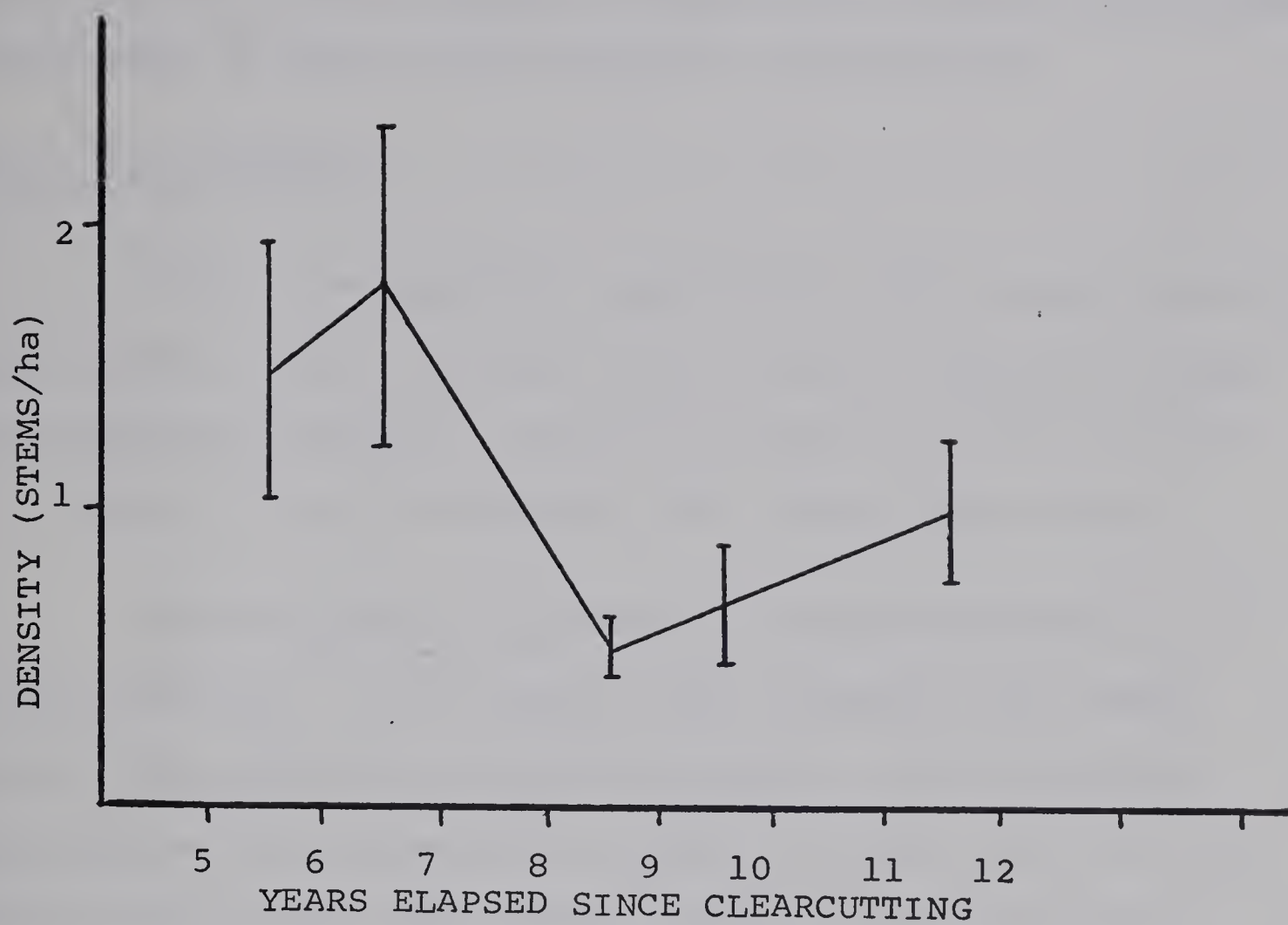
Figures on vertical axis are thousands of stems/ha

FIGURE 34. Black and white spruce regeneration density from 5-12 years after clearcutting

Means  $\pm$  standard errors for each year are given.

n = 5

Figures on vertical axis are hundreds of stems/ha





early period. Pine density and mortality data in the current study seem to agree with Crossley's observations.

### Other Tree Species

Other tree species' reproduction that occurs to varying degrees on the clearcut blocks sampled include in order of decreasing density: *Populus balsamifera*, *Picea mariana* + *P. glauca*, *Abies lasiocarpa*, and *Betula papyrifera*.

Balsam poplar is present in varying amounts in all stands studied. It is usually less abundant than aspen poplar and generally of shorter stature. Balsam poplar regenerates more densely on a moist severely scarified substrate where often the surface mineral horizon has been removed. Mature balsam poplar are uncommon in the study area, being restricted to stream banks and pond margins. The balsam poplar regeneration characteristic of all stands is therefore most likely a result of seeding rather than vegetative root suckering as is the case for aspen. Balsam poplar does not presently form a significant proportion of the mature lodgepole pine forest. It is absent in all but three of the adjacent forest controls. The scarcity of balsam poplar is probably due to its inability to obtain sufficient moisture from the drier soils in the mature forest due to the increasing soil moisture demands of the maturing lodgepole pine. The often abundant reproduction (up to 1800



stems/ha) is probably made possible by the temporarily moister conditions of the clearcut blocks.

For the period elapsed since the first cut in 1958-59, analysis of variance and Duncan's Multiple Range Test showed no significant difference between years (Fig. 33) for balsam poplar density, indicating that the predicted demise of balsam poplar may not occur for some time.

*Picea mariana* and *P. glauca* were of sporadic occurrence in all stands but two. Both species of spruce are grouped in the regeneration tables due to the difficulty of distinguishing between black and white spruce seedlings. Seedlings of these species, of which black spruce is more abundant, tend to occur in small groups where a mature spruce stood before the clearcutting operation. Field observations suggest that spruce seedlings are more abundant near the edges of the blocks, and therefore, closer to the seed source in the mature forest. Spruce seedlings also tend to be limited to areas of bare mineral soil more so than pine and aspen and are usually of very small and inconspicuous stature in the stand.

Spruce is still regenerating in many stands and along with the advance growth of black spruce left in several stands, may assume a more important role in the forests of the future. This seems likely because low to moderate densities



of black and white spruce occur in all but six of the adjacent forest control areas. The mature black spruce are approximately the same age as the pines as shown by increment cores, making allowance for the longer time required for black spruce to become 1.5m tall. Analysis of variance and Duncan's Multiple Range Test show no significant difference between years for spruce regeneration density (Fig. 34) and the apparent decline in Fig. 34 is probably not real.

Paper birch (*Betula papyrifera*) is uncommon in the study area, with regeneration recorded in only 3 stands. Stand 12 however has a birch density of 3800 stems/ha, with some individuals reaching heights of 3 meters indicating possible vegetative regrowth from stumps. Paper birch was fairly abundant on this stand before clearcutting as shown by the number of fallen birch trees which, apparently owing to their smaller size, were not hauled away with the pine. Stand 12 is unique in several other respects which are discussed in other sections of this thesis. Birch density is greater than that of pine and approximately equal to that of aspen in stand 12. Birch will probably form a significant proportion of the mature forest following secondary succession. Birch also occurred in stand 16 with a density of 300 stems/ha. All individuals were less than 0.5 meters tall indicating that they probably arose from seed in contrast with much taller individuals in stand 12 which was cleared only



PLATE 5. A moist logging trail in a 12 year old stand (Block 6, near stand 3) showing balsam poplar and absence of aspen on the trail.



PLATE 6. A dry logging trail in a 12 year old stand (stand 1) showing absence of woody regeneration on trail.

Tallest pines on edge of trail; clover growing where surface mineral soil horizon removed; grasses (mostly *Phleum pratense* and *Agrostis* sp) growing where surface mineral horizon is exposed, *Achillea millefolium* growing in band on litter at edge of trail on left.





one year earlier.

Subalpine fir (*Abies lasiocarpa*) also shows a very sporadic distribution in the stands studied (Table 8), occurring in only 4 of 25 stands. Proximal fir seed sources to the blocks studied were not abundant. Mature seed-producing fir trees were not seen in any of the adjacent forest control areas, but are common above 1155m toward the north end of the Marlboro 7 working circle.

### iii. Factors Affecting Tree Regeneration

#### a. Scarification

It has been shown previously that a bare mineral seedbed is a prerequisite to successful regeneration of lodgepole pine (Crossley 1956a, Hughes 1967, Lees 1970).

Successful scarification not only allows pine seeds to come in contact with mineral soil but, at the same time, re-covers the exposed mineral soil with a thin layer of litter. Once contact with mineral soil has been made by the seed, the litter covering is no longer a barrier but serves as a mulch to conserve soil moisture and prevent seedling dessication. Successful scarification appears to have been accomplished in the study area, as the amount of exposed mineral soil is quite low (0.3 to 12.6%, Table 9). A mechanical scarification of the soil surface also facilitates



vegetative reproduction of aspen poplar by root suckering (Maini and Horton 1966) when residual aspen poplar roots are cut and bruised by the scarifier blade. Even if the roots are not bruised, the stored carbohydrate reserves will often enable the aspen roots to grow new shoots. The result of this type of vegetative reproduction is the formation of an aspen clone where there was only one tree. An insolation-induced increase in soil temperature usually plays a critical positive role in sucker initiation (Maini and Horton 1966). Soil temperatures on the clearcut blocks are discussed on page 115.

Deep scarification of the ground, involving removal of the surface mineral horizon (Ae) as well as part of the second mineral horizon (Bt) has somewhat different effects upon tree regeneration. This type of seedbed usually occurs where logging trails run through the cleared area. The effect of this heavy scarification and compaction is most evident on the older (12 year) stands, where tree regeneration has had ample time to become established.

One of the more pronounced features of the bladed trails is a substantial decrease in aspen poplar regeneration as compared to the unscarified or lightly scarified areas on either side, as in stand 3 (Plate 5). This difference is apparently the result of removal or killing of the aspen



roots thus prohibiting on-site vegetative reproduction of aspen except by invasion from the sides. Lesser amounts of alder (*Alnus crispa*) on these trails can probably be accounted for in the same manner.

Where a block road passes through what is now an area of dense aspen, pine is frequently denser and taller on it than on either side. This effect may be due to reduction in root competition with the aspen. The abundance of balsam poplar up to 3 meters tall with the pine on these trails (Plate 5) suggests that scarification has either directly or indirectly altered the moisture regime of the soil surface, making it moister, or reduced competition with aspen, or both. Balsam poplar was absent in the young stand adjacent to the trails of this type in blocks 4 and 6 (stand 3).

Tree regeneration appears somewhat different on deeply bladed logging trails that pass through areas where aspen is absent or not at all abundant on either side of the trail. On roadbeds of this type (such as occur in stands 1 (Block 2) and 5 (Block 9), pine regeneration is excellent on both sides but woody plants are nearly absent on the roadbed itself (Plate 6).

This second condition apparently occurs on somewhat drier areas as evidenced by the lack of balsam poplar repro-



duction. Although pine regeneration is almost absent on the trail in stand 1, the pines growing on the piles of soil and organic matter on the roadside are conspicuously taller, with many individuals exceeding 3 meters, compared to the remainder of the stand where individual pines of this height are very rare (Fig. 25). This condition is an apparent result of the added nutrients from the stripped soil and organic matter.

To account for the differences in the trends of tree regeneration on the trails, one must consider the altered soil moisture and nutrient regimes, soil compaction as well as the questionable lodgepole pine seed supply on these trails as they are often relatively slash-free.

#### b. Moisture Regime

The relationships of stand density of pine, aspen and other species to soil moisture were discussed in the Ordination of Stands section. It now seems appropriate to elaborate upon the tree density results using field observations of pine and aspen distribution.

The study area includes excellent to marginal areas for pine and aspen regeneration. The habitat preferences of lodgepole pine and aspen appear to be very similar in the area (Fig. 13, ordination). Both species prefer well-drained



sites and are not abundant in the moist areas which support a high cover of bluejoint grass (*Calamagrostis canadensis*). Aspen, however, seems to prefer slightly moister conditions than pine, and is often found where slight variations in stand topography have created moister lower areas. Aspen though is by no means restricted to low areas although it does seem to require more soil moisture than pine. Aspen distribution can be accounted for in part by local variations in soil texture and drainage. Aspen density in the study area appears to be highest on the finer textured clay and heavy clay soils which tend to have more available moisture than the coarser loams and sandy clay loams.

### c. Logging Slash

Prerequisite to successful pine regeneration after logging is a moderate slash cover. It is essential, both as a seed source and also as protection for seedlings from temperature extremes, dessication, grazing animals, and intolerant vegetation (Smith 1962). A heavy slash cover, however, is a fire hazard, hinders establishment of reproduction through shading and mechanical effects, and may provide areas where undesirable grasses, herbs and shrubs can persist, often for long periods of time (Smith 1962). Such heavy slash areas occur in the Marlboro 7 working circle, especially where a moderate density of unmerchantable black



spruce was present in the original stand. In these areas, logging slash is often in substantial piles up to 1.5m deep and several m across. Pine regeneration is usually absent under these piles for the reasons given above. These slash piles are, however, favorable habitats for growth of *Rosa acicularis* and *Rubus strigosus*.

#### d. Competition

Inhibition of silviculturally desirable tree species by other tree, shrub, forb or grass species has long been a deterrent to satisfactory conifer regeneration. The low shrubs, grasses and other growth of open areas do not cast as much shade as a mature forest but can cause even more root competition to tree seedlings (Smith 1962).

It was not possible to quantitatively evaluate interspecific competition in this study. However, several species do appear to be associated with inadequate pine regeneration (see pages 93-95 ). Where bluejoint grass is abundant, pine regeneration density is low. A negative correlation between lodgepole pine density and bluejoint cover on the three densest and three least dense pine stands is significant at the 5% confidence level ( $r = -0.817$ ). This correlation is not significant when all stands were considered, as the stand area was large enough that it often contained extremes in soil moisture as well as other environmental gradients, resulting

FIGURE 35. Logging slash cover from 5-12 years after clear-cutting

Means  $\pm$  standard errors for each year are given.

n = 5

FIGURE 36. Litter depth from 5-12 years after clearcutting

Means  $\pm$  standard errors for each year are given.

n = 5

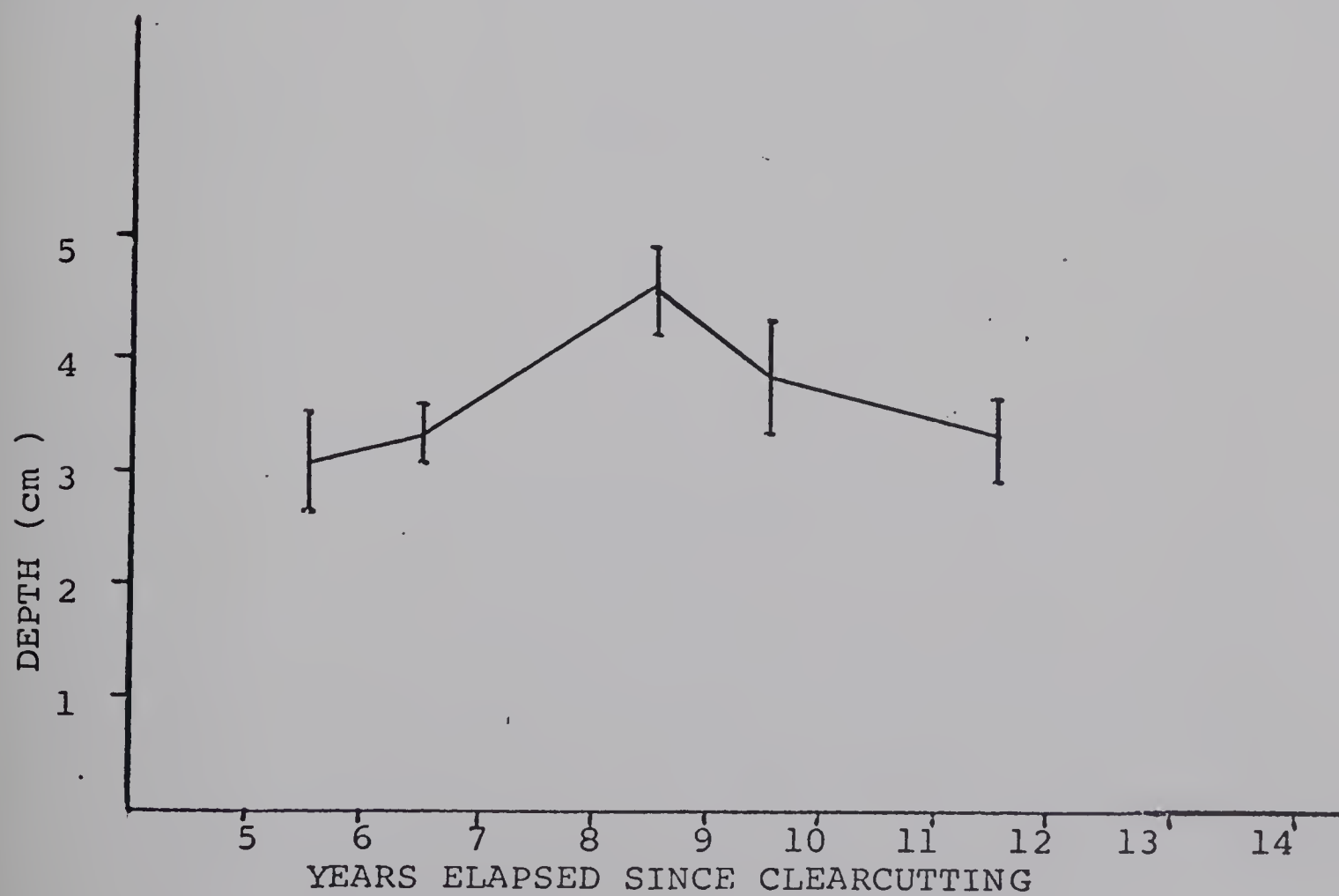
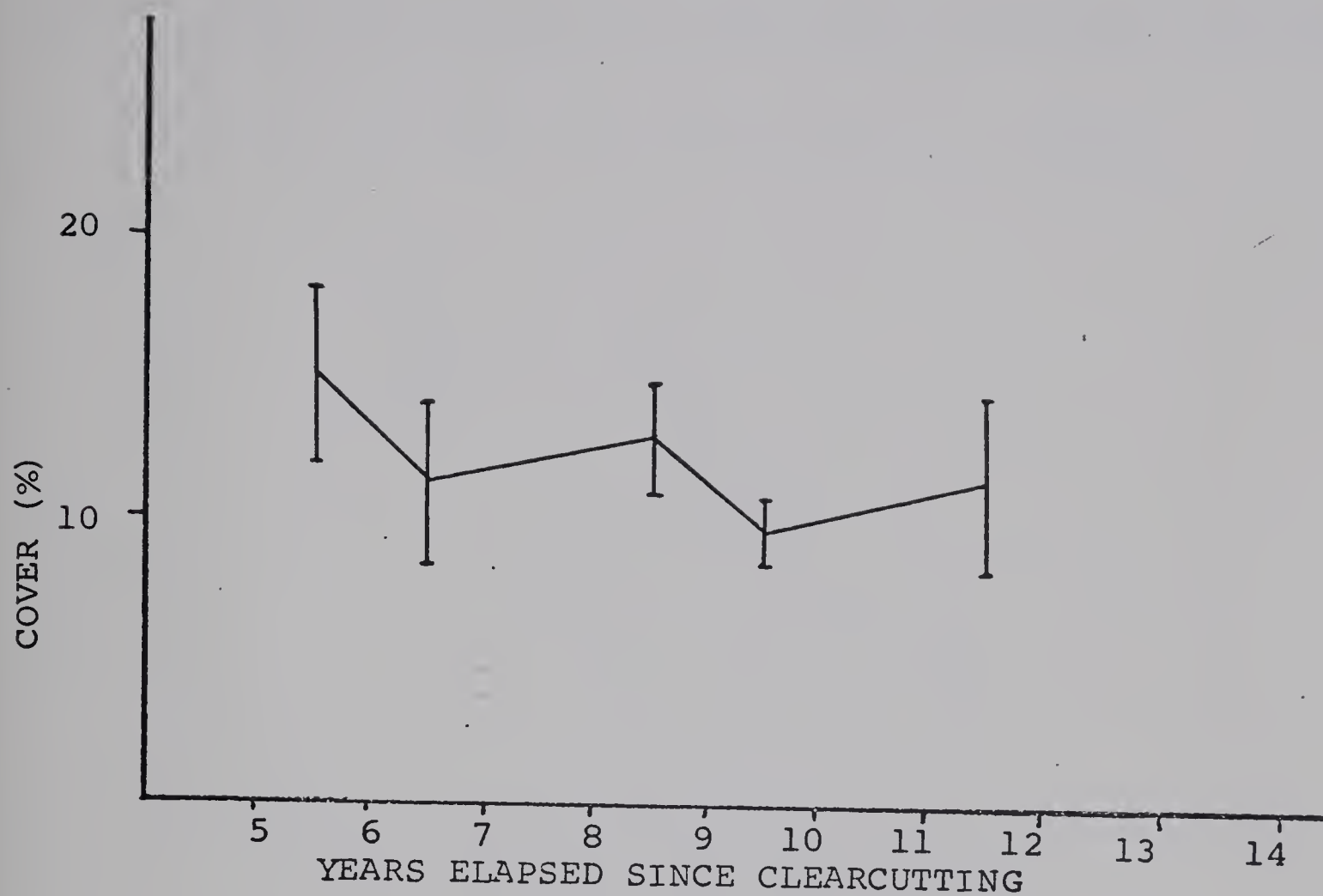


FIGURE 37. Bare duff cover from 5-12 years after clearcutting

Means  $\pm$  standard errors for each year are given.

n = 5

FIGURE 38. Stand disturbance from 5-12 years after clearcutting

Means  $\pm$  standard errors for each year are given.

n = 5

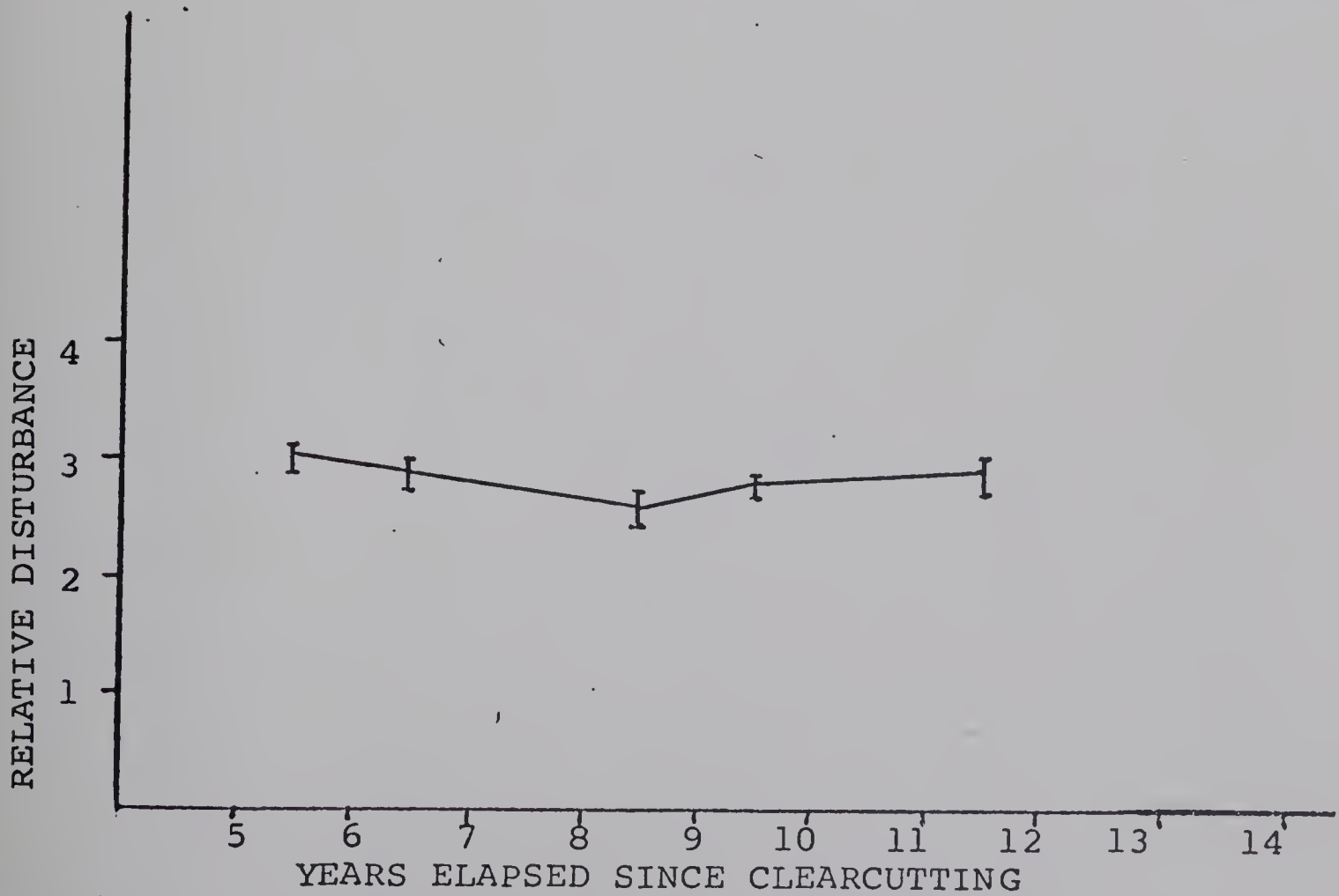
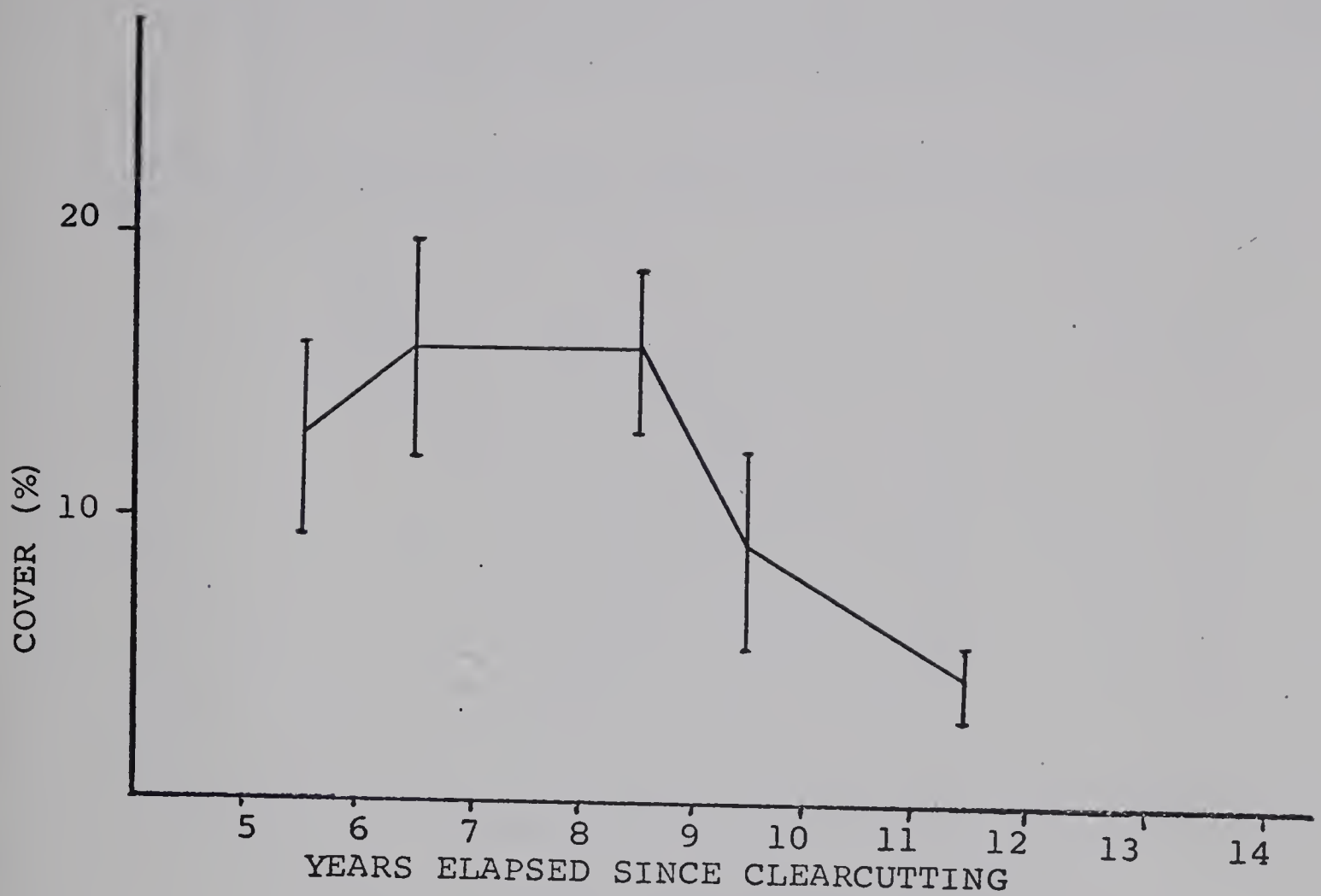


FIGURE 39a. Uncorrected soil temperature at 20cm. depth  
from 5-12 years after clearcutting

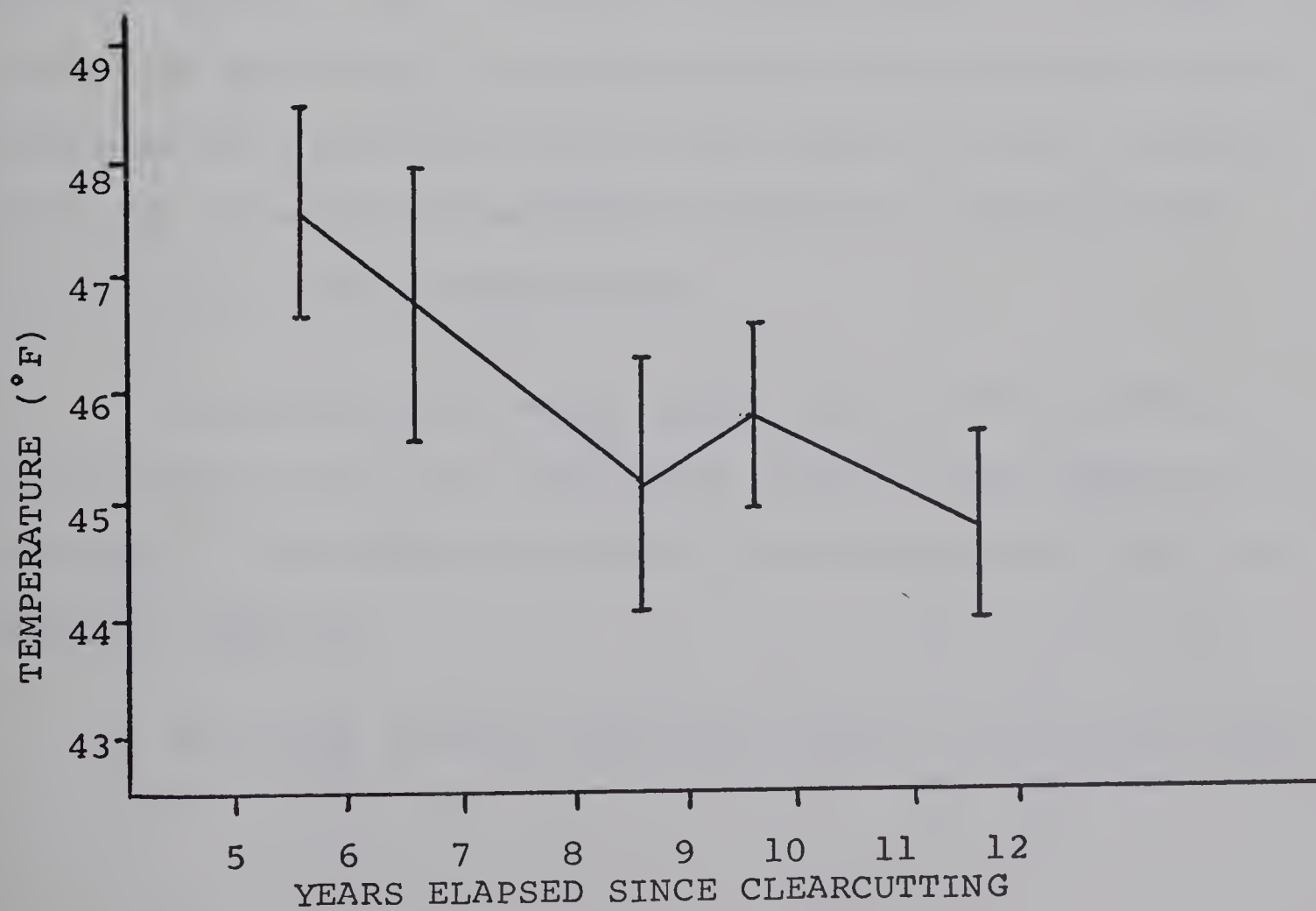
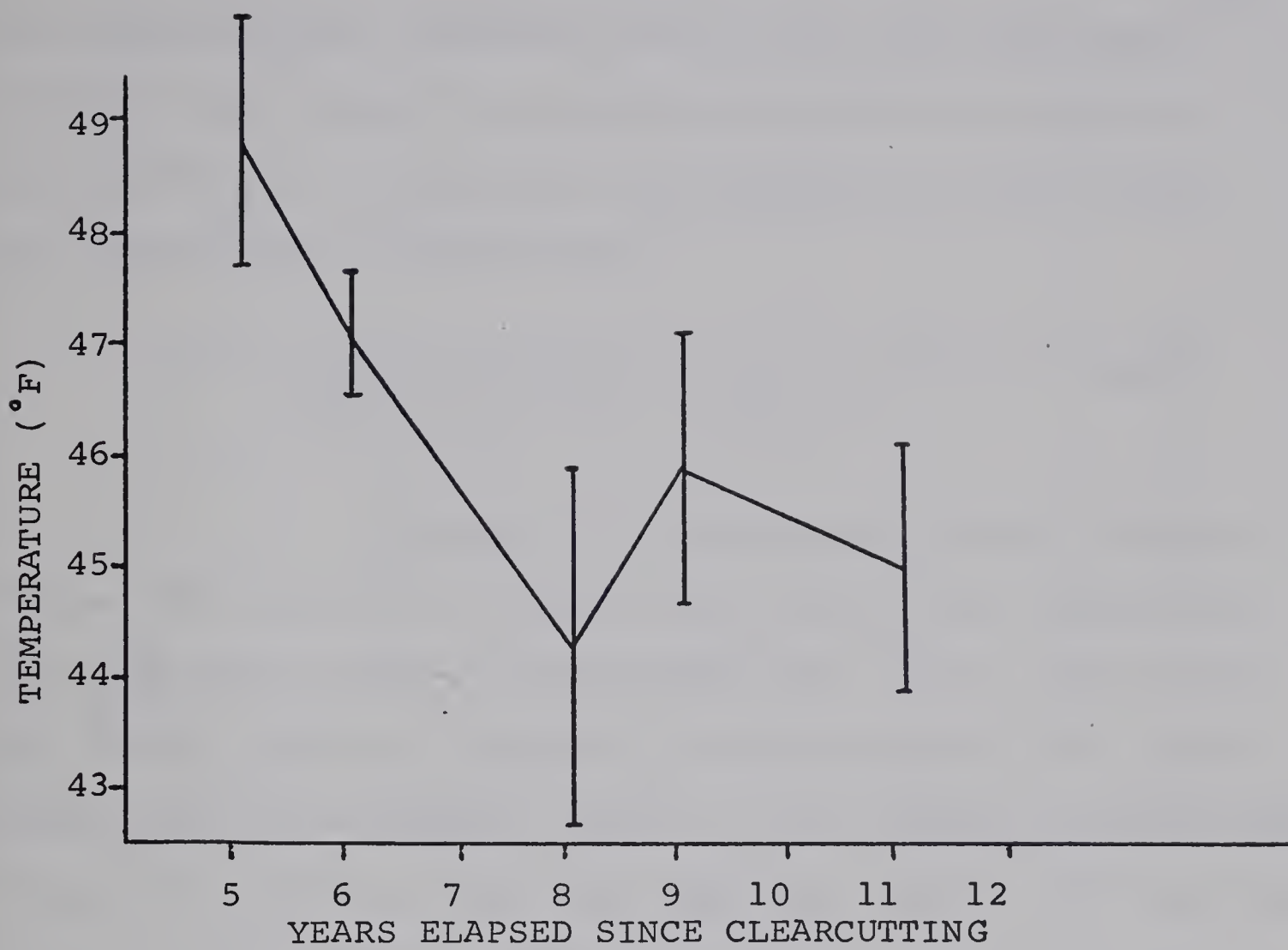
Means  $\pm$  standard errors for each year are given.

n = 5

FIGURE 39b. Soil temperature at 20cm. depth from 5-12 years  
after clearcutting

Means  $\pm$  standard errors for each year are given.

n = 5





in between-stands variation being less than that within stands, with respect to abundance of pine and bluejoint. Implications of competition are discussed in the section on Silvicultural Implications.

iv. Physical Habitat Characteristics of Stands  
From Quadrat Data (Table 9)

Analysis of variance and Duncan's Multiple Range Test revealed no significant differences among years for dead grass cover, bare mineral soil cover, slash cover, and litter depth as assessed in the 30 quadrats per stand. Slash cover does appear, however, to be gradually decreasing (Fig. 35). Decay is the most important factor involved here. Litter depth increases until 8-9 years after logging then decreases (Fig. 36). This can be explained by a buildup of litter as the slash is breaking down and losing its needles followed by a decline during which slash is still breaking down but as shade and moisture increases, decomposition occurs faster than accumulation.

The difference among years for bare duff cover is significant at the 10% confidence level, using analysis of variance. The results of Duncan's Multiple Range Test are shown in Table 6.

The plot of bare duff cover (Fig. 37) is very simi-



TABLE 9. PHYSICAL HABITAT ATTRIBUTES FROM 1x1 m QUADRATS

		Cut 1958-59					Cut 1960-61					Cut 1961-62				
BLOCK NO.	2	5	6	7	9		1N	2N	8N	11	12	10N	22	28	32	9N
STAND NO.	1	2	3	4	5		6	7	8	9	10	11	12	13	14	15
ATTRIBUTE:																
Slash	C <sup>a</sup> F <sup>b</sup>	8 67	6 47	7 50	23 87	12 73	11 83	9 70	12 83	10 70	7 63	12 70	6 43	17 93	16 87	13 73
Bare duff	C	4	3	5	8	7	20	6	13	6	11	16	10	23	21	10
	F	23	13	27	43	43	70	23	50	27	43	43	70	80	67	50
Bare mineral	C	1	-	5	4	1	4	2	+	7	-	11	1	1	1	1
soil	F	10	-	7	17	13	27	3	10	20	-	17	7	7	10	7
Dead grass	C	1	13	7	4	4	6	2	4	2	3	1	25	4	6	3
	F	13	57	37	23	20	33	7	27	10	13	3	70	23	37	13
Disturbance <sup>c</sup>		2.6	3.0	2.7	3.3	3.1	2.8	2.7	2.8	3.0	2.6	2.4	3.0	2.7	2.4	2.4
Uniformity <sup>c</sup>		2.5	2.3	2.6	3.2	2.1	2.5	2.7	2.2	2.4	2.7	2.6	2.8	2.9	2.6	2.8
Litter depth (cm)		2.8	3.0	3.8	2.5	4.3	3.3	3.6	4.3	2.5	5.6	5.3	5.3	3.3	4.3	4.1
Soil Temp. <sup>d</sup>																
Uncorrected		44.8	44.9	42.5	47.3	45.7	46.3	43.3	47.4	47.6	44.9	42.8	41.4	45.5	48.0	43.7
(°F) corrected		41.4	42.5	45.7	47.3	46.4	47.6	43.3	48.7	46.8	42.5	47.3	49.9	48.0	45.6	40.5
Sampling Date																
Day	4	6	23	18	12		22	26	9	5	25	30	30	19	13	1
Month	7	7	6	7	7		7	6	7	7	6	6	6	7	7	7

a - percent cover; b - quadrat frequency; c - from 4- point subjective scales (Appendix 1);

d - at 20 cm depth; - - missing data. + - cover less than 0.5 %



TABLE 9. Cont'd.

ATTRIBUTE:	Cut 1963-64						Cut 1964-65						Mean
	60	68	114	116	121	71	102	103	122	123	24	25	
	16	17	18	19	20	21	22	23	24	25			
Slash	8	6	17	7	19	17	10	7	24	18			12.1
	47	57	80	57	77	77	83	60	80	87			70.6
Bare duff	19	15	17	3	26	9	17	18	13	25			13.0
	53	47	77	20	77	53	60	77	43	80			50.4
Bare mineral soil	4	3	5	+	2	8	4	-	13	8			3.9
	17	27	27	3	30	40	30	-	47	30			18.5
Dead grass	+	-	2	5	-	1	4	2	-	2			4.6
	17	-	13	33	-	3	20	13	-	17			22.8
Disturbance <sup>c</sup>	2.7	3.2	3.1	2.9	2.7	3.1	3.1	2.8	3.2	2.9			2.8
Uniformity <sup>c</sup>	2.2	2.6	2.4	2.6	2.2	2.5	2.0	2.6	3.1	3.0			2.6
Litter depth (cm)	3.6	3.0	2.8	3.0	4.3	2.8	2.8	1.9	4.6	2.5			35.7
Soil Temp. <sup>d</sup>													
Uncorrected	47.7	47.4	48.9	42.5	49.2	49.6	49.0	46.3	51.1	47.8			46.2
(°F) corrected	47.2	49.0	48.0	45.7	47.0	49.6	48.0	44.6	48.5	47.2			46.3
Sampling Date													
Day	3	27	16	2	8	10	20	24	7	7			
Month	7	6	7	7	7	7	7	6	7	7			



lar to that of litter depth and can be explained in the same manner.

Analysis of variance revealed no significant difference among years for stand uniformity ( $\bar{x} = 2.56$ ), indicating that it will likely be several years before the vegetation approaches the 1-2 uniformity rating associated with the mature forest.

Stand disturbance on the other hand, proved to be significantly different (5% confidence level) among years. Stands cleared in 1961-62 had a significantly lower mean disturbance ( $\bar{x} = 2.58$ ) than the other years (Fig. 38). This implies that scarification on these stands was not as intense as on the others. This may explain the deeper litter on these stands (Fig. 36). The lower disturbance rating and deeper litter combined may account for the lowest total plant cover (Fig. 13) and lowest balsam poplar density (Fig. 33) on stands cleared during 1961-62.

Analysis of variance for group mean soil temperature at 20cm depth for each set of five stands cleared within a given year (Fig. 39a) show differences significant at the 5% confidence level among years using soil temperatures uncorrected for ambient air temperature. There is an evident tendency for summer soil temperatures to be higher in recently cutover than in older cutover stands.



PLATE 7. Rapid increase of *Calamagrostis canadensis* on block 177 the summer after clearcutting.

*Calamagrostis* had negligible cover on the block on June 1, 1 month before photo taken. *Calamagrostis* still formed a very small fraction of the plant cover in the mature pine forest adjacent.



PLATE 8. Stand 19 illustrating the *Calamagrostis* type.





The correlation coefficient between mean soil temperature in the 25 stands on the date sampled and ambient air temperature for the same date is positive and significant at the 1% confidence level ( $r = +0.549$ ). The linear regression equation for prediction of the corrected mean stand soil temperature is  $T = 25.95 + 0.33X$  at a constant  $60^{\circ}\text{F.}$  at Edson, and was used to remove day to day air temperature differences from between stand comparisons.

Analysis of variance for group mean soil temperatures for each set of five stands cleared within a given year do not show significant differences among years using soil temperature corrected for ambient air temperatures (Fig. 39b). The corrected soil temperatures show the same trend but not so pronounced as the uncorrected temperature values.

Diurnal soil temperature differences at 20cm. are probably greater than the  $2.8^{\circ}\text{F.}$  difference between group mean temperatures for 1958 and 1964. Consequently, this is probably of very little biological significance. It does however probably reflect vegetation changes in the cleared blocks and the trend back to a forest soil temperature regime.

#### v. Silvicultural Implications and Application

The relationship between lodgepole pine and bluejoint may have important silvicultural implications. Al-



though not dealt with specifically in this study, cleared blocks above 1170m were decidedly moister than most of the stands in the study area. These blocks typically had a higher cover of bluejoint and extremely sparse lodgepole pine regeneration. Although bluejoint cover increases very rapidly after clearcutting (Plate 7), it takes several years before a thick sod is formed over the area.

On these moist sites where bluejoint is a potential competitor with lodgepole pine seedlings, it may be desirable to plant the area to pine or white spruce during the summer immediately following clearcutting in order to give the seedlings a chance to become established before they are smothered by competing grasses. The current restocking policy of Northwestern Pulp and Power is to make a regeneration survey 7 years after logging. In areas where natural regeneration is inadequate as defined by several criteria (Appendix 3), restocking according to recommendations is done the following year. This delay of several years in restocking has resulted in the establishment of a thick bluejoint sod in several blocks, and increased competition for planted tree seedlings.

Tree planting as soon as possible after logging on moist sites may offer an alternative to natural reproduction, as natural reproduction appears likely to be inadequate



for forestry, where bluejoint is dominant. However, before initiating such a procedure it would be advisable to learn more about the relationship between lodgepole pine and bluejoint.

It is similarly difficult to determine the relationship between pine and aspen. These two species are close in their habitat preferences as shown by the ordination (Fig. 13). However, pine is generally not abundant within the aspen clones, where it is usually shady, and where aspen root density is greatest.

More research is required to clarify the relationships of lodgepole pine and aspen poplar and their competitive interactions. I was unable to find information of this type dealing with pine and aspen. Steneker and Jarvis (1963), working in the boreal forest of Saskatchewan, found negative correlations between spruce annual diameter increment and basal area of surrounding aspen trees. A competitive effect of aspen upon white spruce was shown by Steneker (1967). He found experimental cuttings of aspen in mixedwood stands doubled diameter increment and, in some cases height increment of white spruce. Lees (1966) made similar observations. A study directed toward this aspect of lodgepole pine forest succession might yield valuable information on whether or not aspen will continue to be less



desirable as a source of pulp for paper than pine and other conifers of the Alberta Foothills.

#### E. Site Classification

A completely physiographic evaluation of site (Hills 1952) is neither possible with the limited physiographic data available nor do I consider an evaluation of this type desirable for the Edson area. As noted earlier, Rowe (1962) emphasized the desirability of a classification based upon a three-way correlation between key indicator plants, topographic-moisture gradients and forest growth. He stated though that some minor species may not reflect conditions of importance to deeper rooted trees.

A simple site classification based upon the same attributes mentioned by Rowe can be applied to the young pine stands of the study area. Two fairly distinctive types can be designated — A *Calamagrostis* type and an *Elymus* type.

The *Calamagrostis* type is not well represented in the stands but is typical of the area to the north of the study site. It is dominated by a luxuriant growth of *Calamagrostis canadensis* (Plate 8) and usually inadequate pine regeneration. Aspen is absent or nearly so. This type is most common on the moist higher precipitation sites



at higher elevations. The soils may be poorly drained as apparent in one such block (#130) on the plateau north of the study area, where standing water was present on the ground surface two days after a 5cm. rainfall which was readily absorbed by the soil within other stands. *Calamagrostis canadensis* may be inconspicuous in the mature pine forest but is capable of quickly dominating a cleared block. The thick sod which develops within a few years after logging on sites of this type, in addition to excessive moisture, lessens the chances for survival of germinating pine. It should be emphasized that, although the moist *Calamagrostis* sites are undesirable for pine regeneration, they may be superlative for tree growth once the trees are established to such an extent that they overcome root competition with *Calamagrostis*. The trees may then be able to utilize the moisture that would have "drowned" them in the seedling stage. Block 177, which was logged in the winter of 1969 and developed a lush *Calamagrostis* cover during the course of the following summer had stumps which, at 68 years of age, exceeded 38cm. in diameter, exceptionally large for the Edson area. Although it was still too early to evaluate regeneration success, block 177 appears similar to other high altitude stands on the plateau to the north of the study area logged several years earlier, which now show very sparse pine regeneration.



The *Elymus* type predominates in the stands sampled. It is typified by a luxuriant growth of *Elymus innovatus*, usually abundant pine, and variable amounts of aspen. This type is uncommon above 1170m, north of the study area. At the lower elevations soils are well drained and precipitation is somewhat less than at the higher elevations. *Elymus* also increases in cover after logging and is often abundant in the mature pine forests adjacent to the cleared blocks. It does not appear to form a dense sod as does *Calamagrostis canadensis*. The *Elymus* type thus favors faster, denser pine and aspen regeneration than does the *Calamagrostis* type. Cover of *Elymus* in the three stands where it is most abundant and in the three where it is least abundant, is correlated with the density of aspen in those stands ( $r = +0.85$ ), insignificant at the 5% confidence level.

#### F. Animal Activity

The following report is based upon general observations during the summer of 1970. Logging has a distinct effect upon the animal life in the study area. Several differences are evident between the uncut forest and clearcut blocks with respect to the number and abundance of ungulates, predators, insects, arachnids, rodents and toads.

Mule deer were common on the clearcuts and were sighted every 3-4 days. Evidence of browsing and deer rest-



ing spots was common particularly on the 12 year old clear-cuts where aspen browse and cover were most abundant. Stand 12 (Block 22) suffered severe damage to the young pine, with leaders browsed off more than 60% of the young trees. Alder formed a dense understory in this stand but did not appear to be heavily browsed. Summer use of grass or forbs by ungulates was not evident in the study area. The cleared blocks provide browse for the mule deer and moose (much less abundant), that is not present in the mature pine forest.

The logging operation has had an apparently detrimental effect upon the population of black and grizzly bears. Black bears were once common in the area, several being shot at the Camp 20 garbage dump in past years. Grizzly bear sightings are now much less frequent (personal communication, N.W.P. & P. workers). The increased activity of the oil and construction industries in addition to the logging operation has apparently forced the bears farther back from civilization. No bears were seen in the study area by the author during the summer of 1971 although bear tracks were seen on two occasions. Coyotes were often heard in the evening on nearby cleared blocks and coyote feces were seen regularly. Coyotes are probably important in regulating rodent populations in the area.

Arachnids and several insects appear much more



abundant on the ground in clearcuts than in the forest. Spiders were extremely abundant on the cleared areas and were especially active on warm days. Ants were also very abundant on the clearcuts. Ants move into an area very soon after it is cleared and commence to break down the residue of the logging operation. Ant colonies are present throughout the blocks in tree stumps and in areas of high slash concentration. Even on the 6 year old blocks ants had destroyed the tree stumps to such an extent that it was not possible to get adequate disc samples for determination of original stand history.

Wasps may also be abundant on the clearcut blocks. Slash piles are favorable nesting spots. Grasshoppers were also common on the clearcuts and appear to be restricted to these areas. They were inconspicuous in the forest.

Another conspicuous creature common on the clearcuts was the western toad (*Bufo boreas*). The food supply for the toad is abundant.

Rodents were not conspicuous on the cleared blocks. Redback voles were seen occasionally. Red squirrels were fairly common in the pine forest but never observed on the clearcuts. Rodents are no doubt more susceptible to both bird and mammal predation in the open areas than in the forest.



## VIII. SUMMARY AND CONCLUSIONS

### A. The objectives of this study were:

1. To describe and characterize the initial stages of secondary plant succession and tree regeneration after pulpwood clearcutting of mature lodgepole pine forests in the Low Foothills Section of the Boreal Forest Region of Alberta, by quantitative sampling of structural and phytosociological attributes and plant production.
2. To relate these attributes to the environment.
3. To briefly describe the structure and floristic composition of the mature, undisturbed pine forests in the study area.

### B. Using large scale forest cover maps and ground reconnaissance, 25 blocks, representing clearcuts of 5 different years between 1958 and 1965, were selected. The stands were selected such that:

1. The sampling area was within what was pure lodgepole pine before clearcutting, as designated by the forest cover maps and of medium to overstocked density and 50-90 feet in height.
2. Stand areas were on topography of minimum relief and as level as possible in order to reduce variation in stands due to topographic and edaphic factors.



- C. Restricted random sampling was done within a stand area of 100 x 200 yards. Three random points along the master baseline in the center of the stand were the points of origin for 1m x 100yd. tree regeneration density transects. At 30 random locations along the 3 subsidiary baselines, nested square quadrats were placed to quantitatively sample attributes of the vegetation and physical habitat, 2 x 2 meter quadrats for shrubs and tree regeneration and 1 x 1 meter quadrats for herbs, dwarf shrubs, bryophytes, lichens and physical habitat attributes.
- D. As a result of quadrat and transect sampling observations made within the stand as a whole, estimates were obtained of the following attributes of composition, population and community structure of the vegetation: Presence, quadrat frequency and cover of all vascular species, terrestrial bryophytes and lichens, tree regeneration density and height-age and biomass estimates for pine and aspen regeneration.
- E. Observations in quadrats were made of slope angle and aspect, soil temperature, litter depth, uniformity and disturbance. Soil horizon samples were analyzed for texture, moisture characteristics and available mineral nutrients.
- F. The mature uncut forests of the study area are even-



aged, with all but one stand originating after a fire in 1840. The lodgepole pine dominated forests are being succeeded by black spruce. Aspen comprises up to 51% of the basal area of some of the lower elevation (over 1110m.) forests, Balsam poplar and paper birch are rare. The mature pine forests generally have a poorly developed shrub stratum but a uniform, fairly dense herb-dwarf shrub stratum and an almost continuous feathermoss cover. Vascular species diversity decreased with increased elevation going northward across the study area within the nature forest.

- G. Of the 100 vascular species recorded in quadrats on the clearcut stands, 82 were herbs and dwarf shrubs, 11 were shrubs, and 7 were trees. The floristic uniformity of the clearcut blocks is indicated by 26% of the vascular flora in more than 60% of the stands. A large number of species (83%) however occurred in less than 20% of the 750 quadrats, indicating a scattered distribution of many species, of which a great number are invaders.
- H. Average vertical cover of tree regeneration was 6.6% of which all but 0.5% was made up of pine and aspen in equal amounts. Both pine and aspen showed an increase in cover with time but aspen cover distribution was more irregular than that of pine.



- I. The mean cover of the poorly developed shrub stratum on the clearcut stands was only 1.1%. *Rosa acicularis* (0.6%) was most important followed by *Shepherdia canadensis*, *Viburnum edule* and *Alnus crispa*. The mean height of the shrub species is less than 46cm. resulting in a higher presence and cover in the herb-dwarf shrub stratum. No significant difference in cover among the years was detected for any of the shrub species when tested by analysis of variance.
- J. The mean cover of the herb and dwarf shrub stratum in the clearcut stands was 49.8%, accounting for 87% of the total vascular plant cover. *Epilobium angustifolium*, *Elymus innovatus*, *Calamagrostis canadensis*, *Vaccinium myrtilloides*, *Cornus canadensis*, *Ledum groenlandicum*, *Petasites palmatus*, *Vaccinium caespitosum*, *Rubus pubescens*, and *Linnaea borealis* together comprise 36% of the cover of the clearcut stands.
- K. The species of the highest presence, frequency and cover on the clearcut stands with the exception of *Epilobium*, are also the most abundant species of the mature uncut forest. These species have an advantage over species reproducing by seed on the cleared areas due to their capability for vegetative reproduction by rhizomes or layering of branches.



Only *Vaccinium vitis-idaea* showed a significant increase in cover. All other species of this stratum showed no significant difference among years when tested by analysis of variance.

- L. Mean total cover for all separate vascular plant species was 57.5% and ranged from 38.6% to 101.5%. Analysis of variance revealed no significant differences for total vascular plant cover among years from 6 - 12 years after clearcutting, indicating that the successional vegetation on the clearcut blocks has become well established by 6 years after clearcutting. Indications are that this establishment may well occur within 2 - 3 years after logging.
- M. Where species occur both in the mature forest and on the clearcut blocks, vegetative growth, flowering and fruiting generally occurs on plants of the cleared area before those in the shade of the forest. *Cornus canadensis* and *Vaccinium vitis-idaea* are exceptions. Also, species occurring both in the forest and on the cleared areas are generally more robust, taller and have larger, darker green leaves in the forest than on the cleared areas, with the exception of the grasses *Elymus innovatus* and *Calamagrostis canadensis* of which *Elymus* is more abundant.
- N. Clearcutting of the tree stratum results in a drastic depletion of the light intolerant mosses, which form an



almost continuous cover in the mature forest. The mean total cover of the bryophyte-lichen stratum was 12.5% of which all but 0.5% was moss. Moss cover shows a slight tendency to increase with time after clearcutting, reflecting the closure of the developing tree canopy.

*Polytrichum commune*, *Pleurozium schreberi* and *Hylocomium splendens* are the most important mosses.

O. Lichens have a total mean cover of 0.44%, most of which is attributable to species of *Peltigera*. *Cladonia* spp. compose the greater part of the remaining lichen cover. Analysis of variance reveals a significant increase in lichen cover among years.

P. To investigate the relationships among stands, a two-dimensional ordination was constructed based on an index of dissimilarity between stand pairs with the distances between the stands on the ordination field reflecting vegetational and presumably, physical habitat and historical similarities. The ordination of stands provided a framework on which quantitative data were plotted to detect association between species or correlations between species populations and environmental variables.

Q. The groups of age classes on the ordination field show time-based seral effects and site differences among age classes. On the ordination, only *Vaccinium vitis-*



*idaea* cover and total lichen cover appear to be influenced by stand age, and are most abundant in the oldest stands.

- R. A soil moisture gradient based on gravimetric field soil moisture samples appears to be the most influential determiner of floristic composition and therefore stand position on the ordination field. The species most abundant on the drier sites on the left side of the ordination field are pine, aspen, *Elymus innovatus*, *Vaccinium vitis-idaea* and *Lathyrus ochroleucus*. *Mitella nuda* and *Mertensia paniculata* are most abundant in the moister stands. Total vascular plant cover is least on the moist sites, reflecting the preference of most species for a dry habitat.
- S. Slash cover, bare duff cover, bare mineral soil cover, available soil moisture in the Ae horizon, and soil phosphorous in the Ae horizon are maximum in stands in the upper part of the ordination field. The abundance of these attributes may, in part, account for the higher cover of *Shepherdia canadensis* and *Populus balsamifera*, and the lower cover of *Rubus pubescens*, *Galium boreale* and *Aulacomnium palustre* in stands in the upper part of the ordination field.
- T. The modal ages of pine regeneration on the 6 and 12 year old stands are 4 and 10 years respectively, reflecting a delay in seed release from slash-borne cones or a delay



in scarification of the ground surface of the cleared block or a combination of these. A two year lag is not evident for aspen on the same blocks, suggesting the vegetative mode of reproduction, and also the competitive superiority of aspen over pine in the early stages of regeneration.

- U. Nearly all of the tree regeneration on the clearcut blocks originated after the clearcutting operation, lodgepole pine and aspen being the most important species. Pine and aspen regeneration is well established within 6 years after clearcutting. Aspen grows faster than pine and regenerates for a longer time span than pine as illustrated by the height class distributions of pine and aspen regeneration density.
- V. The pine/aspen biomass per stand ratio appears to be increasing, indicating that the long-term growth potential of the sites studied is better for pine than for aspen. The growth rate of pine has evidently increased in relation to that of aspen during the 6 - 12 year interval.
- W. Several species including *Rubus pubescens*, *Calamagrostis canadensis*, *Viburnum edule*, *Equisetum arvense* and *Mertensia paniculata* where abundant appear to be indicative of a poor site for pine and aspen regeneration, probably due to excess moisture.



- X. Pine and aspen mortality is greatest on the oldest stands but constitutes an extremely small fraction of the total stem density. Mortality is negligible for the other tree species.
- Y. Listed in order of decreasing stem density, balsam poplar, black and white spruce, paper birch and subalpine fir constitute the remaining tree regeneration and collectively they usually comprise a very small fraction of total stem density of the clearcut stands.
- Z. A light mechanical scarification of the ground surface has evidently enhanced tree regeneration of all species. A scarification leaving part of the litter layer intact favors conifer and aspen regeneration as well as growth of natural forest herb and dwarf shrub species. A severe scarification which removes the litter and surface mineral soil horizon appears to hamper conifer and aspen regeneration but favors growth of balsam poplar and introduced herbs and grasses, apparently as a result of the altered soil moisture and nutrient regimes, soil compaction and often scarce conifer seed source.
- AA. A moderate logging slash cover while essential to pine regeneration after the clearcutting operation, hinders regeneration when in deep piles.
- BB. There are no significant differences among years for



dead grass cover, bare mineral soil cover, slash cover litter depth, and stand seedbed uniformity. Bare duff cover is decreasing as plant cover increases and utilization of organic matter occurs. Total plant cover and balsam poplar stem density was least on stands cleared in 1961-62 which had a significantly lower ground disturbance rating and deeper litter. A significant increase in soil temperature at 20cm depth with elapsed time after clearcutting is obscured when soil temperature readings are "corrected" to a constant ambient air temperature, but still shows the same trend; a probable reflection of vegetation cover increase, and the trend back to a forest soil temperature regime.

CC. *Calamagrostis canadensis* is a potential competitor with pine on moist sites, usually at higher elevations in the Marlboro 7 area. This problem may possibly be overcome by planting conifer seedlings before a thick *Calamagrostis* sod develops.

DD. The stands of the study area can be classified into either the moist *Calamagrostis* type, with typically has very low pine and aspen regeneration or a drier *Elymus* type, which generally has adequate pine regeneration, variable aspen reproduction and moderate cover of *Elymus innovatus*. Only two stands were of the *Calamagrostis* type which is common at the higher elevations (over



1173m.) north of the study area.

EE. Clearcutting of the mature pine forest, and other human activities appear to have significantly changed the population sizes of many insects, arachnids, rodents, ungulates and predators.



## BIBLIOGRAPHY

- ANONYMOUS. 1970. Monthly Record, Canada Department of Transport, Meteorological Branch.
- BANNISTER, R. P. 1966. Use of subjective estimates of cover abundance as a basis for ordination. *J. Ecol.* 54:665-674.
- BEALS, E. (1960). Forest bird communities in the Apostle Islands of Wisconsin. *Wilson Bull.* 72:156-181.
- BEIL, C.E. 1966. An ecological study of the primary producer level of the subalpine spruce-fir ecosystem of Banff and Jasper National Parks, Alberta. Unpublished M.Sc. thesis, University of Alberta.
- BLYTH, A. W. 1957. The effect of partial cutting in even-aged lodgepole pine stands. Can. Dept. Northern Affairs and Natural Resources, Forestry Branch, Forest Research Division, Tech, Note No. 61.
- BOUYOUCOS, G. T. 1951. A recalibration of the hydrometer method for making mechanical analysis of soils. *Agron. J.* 43:434-438.
- BRAY, J. R. and CURTIS, J.T. 1957. An ordination of the upland forest communities of southern Wisconsin. *Ecol. Monogr.* 27:325-349.
- BRINKMAN, A. H. 1931. Lichens in relation to forest sight values. *The Bryologist.* 34:66-71.



- CAJANDER, A. K. 1926. The theory of foresttypes. Acta. forestalia fennica. 31:108p.
- COILE, T. S. 1938. Forest classification: Classification of forest sites with special reference to ground vegetation. J. Forestry 36:1062-1066.
- CORMACK, R. G. H. 1953. A survey of coniferous forest succession in the Eastern Rockies. For. Chron. 29:218-232.
- CROSSLEY, D. I. 1952a. White spruce reproduction resulting from various methods of forest soil scarification. Can. Dept. Resources and Development, silvicultural research Note No. 102.
- CROSSLEY, D. I. 1952b. Some observations on lodgepole pine regeneration after clearcutting in strips. Can. Dept. Northern Affairs and Natural Resources, Forestry Branch, Forest Research Division, Silv. Leaf. No. 65.
- CROSSLEY, D. I. 1955a. Lodgepole pine studies at the Strachan experimental block in Alberta. Can. Dept. Northern Affairs and Natural Resources, Forestry Branch, Forest Research Division, Tech. Note No. 19.
- CROSSLEY, D. I. 1955b. The production and dispersal of lodgepole pine seed. Can. Dept. Northern Affairs and Natural Resources, Forestry Branch, Forest Research Division, Tech. Note No. 25.



- CROSSLEY, D. I. 1956a. Mechanical scarification and strip clearcutting to induce lodgepole pine regeneration. Can. Dept. For. Tech. Note No. 34.
- CROSSLEY, D. I. 1956b. Effect of crown cover and slash density on the release of seed from slash-borne lodgepole pine cones. Can. Dept. Northern Affairs and Natural Resources, Forestry Branch, Forest Research Division, Tech. Note No. 41.
- CURTIS, J. T. and MCINTOSH, R. P. 1951. An upland forest continuum in the Prairie Forest Border Region of Wisconsin. Ecology 32: 476-496.
- DUFFY, P.J.B. 1965a. Relationships between site factors and growth of lodgepole pine (*Pinus contorta* Dougl. var. *latifolia* Engelm.) in the foothills section of Alberta. Can. Dept. Forestry Publ. No. 1065.
- DUFFY, P.J.B. 1965b. A forest land classification for the mixedwood section of Alberta. Can. Dept. Forestry Publ. No. 1128.
- DUMANSKY, J. and MACYK T. Soil survey of the Edson-Hinton area (83F) Unpublished.
- GIMINGHAM, C.H., PRITCHARD, N.M. and CORMACK, R.M. 1966. Interpretation of a vegetational mosaic on limestone in the Island of Gotland. J. Ecol. 54: 481-502.
- HERINGA, P.K. and CORMACK, R.G.H. 1953. Relation of soils and ground cover vegetation in even-aged pine stands of central Alberta. For. Chron. 39: 273-278.



- HILLS, G. A. 1952. The classification and evaluation of site for forestry. Research Report No. 24. Ontario Dept. of Lands and Forests. Division of Research.
- HNATIUK, R. J. 1969. The *Pinus contorta* vegetation of Banff and Jasper National Parks. M.Sc. Thesis, Univ. of Alberta (unpublished).
- HORTON, K. W. 1953. Causes of variation in stocking of lodgepole pine regeneration following fire. Can. Dept. Northern Affairs and Natural Resources, Forestry Branch, Forest Research Division, Silv. Leaf. No. 95.
- HUGHES, E. L. 1967. Studies in stand and seedbed treatment to obtain spruce and fir reproduction on the mixed-wood slope type of Northwestern Ontario. Can. Dept. Forestry, Publ. No. 1189.
- ISAAC, L. A. 1943. Reproductive habits of Douglas fir. Pub. for U. S. Forest Service by C. L. Pack, Forestry Foundation, Washington, D. C. pp. 51-59.
- LEES, J. C. 1966. Release of white spruce from aspen competition in Alberta's spruce-aspen forest. Can. Dept. Forestry, Publ. No. 1163.
- LEES, J. C. 1970. Natural regeneration of white spruce under spruce-aspen shelterwood, B-18a forest section, Alberta. Can. Dept. Fisheries and Forestry, Can. Forestry Service, Publ. No. 1274.



- MAINI, J. S. and HORTON, K. W. 1966. Reproductive response of *Populus* and associated Pteridium to cutting burning and scarification. Can. Dept. For. and Rural Dev. Forestry Branch publication No. 1155.
- MOSS, E. H. 1959. Flora of Alberta. University of Toronto Press, Toronto. 546p.
- ROED, 1968. Surficial geology of the Edson-Hinton area, Alberta. Ph.D. thesis, Dept. of Geology, University of Alberta, Edmonton. Unpublished.
- ROWE, J. S. 1959. Forest regions of Canada. Can. Dept. Northern Affairs and Nat. Resources, Forestry Branch, Bull. 123. 71p.
- ROWE, J. S. 1961. Critique of some vegetational concepts as applied to forests of northwestern Alberta. Can. J. Bot. 39:1007-1017.
- ROWE, J. S. 1962. Soil, site and land classification. For. Chron. 38:420-432.
- SMITH, D. M. 1962. The practice of silviculture. John Wiley and Sons, Inc., New York. 578p.
- SMITHERS, L. A. 1961. Lodgepole pine in Alberta. Can. Dept. Forestry Bulletin No. 127.
- STEEL, R. G. D. and TORRIE, J. H. 1960. Principles and procedures of statistics. McGraw-Hill Book Company, Toronto. 481p.
- STENEKER, G. A. and JARVIS, J. M. 1963. A preliminary study to assess competition in a white spruce-trembling aspen stand. For. Chron. 39:334-336.



- STENEKER, G. A. 1967. Growth of white spruce following release from trembling aspen. Can. Dept. Forestry and Rural Development, Forestry Branch Publ. No. 1183.
- STRINGER, P. W. and LA ROI, G. H. 1970. The Douglas fir forests of Banff and Jasper National Parks, Canada. Can. J. Bot. 48:1703-1726.
- SUTTON, R. F. 1964. Effects of some stand and seedbed ments of lesser vegetation in a boreal Ontario mixedwood. Can. Dept. Forestry Publ. No. 1090.
- WALDRON, R. M. 1966. Factors affecting natural white spruce regeneration on prepared seedbeds at the Riding Mountain Experimental Area, Manitoba. Can. Dept. Forestry and Rural Development, Forestry Branch Publ. No. 1169.
- WEST, N. E. and CHILCOTE, W. W. 1968. *Senecio sylvaticus* in relation to Douglas fir clear-cut succession in the Oregon coast range. Ecology 49:1101-1107.
- YERKES, V. P. 1960. Occurrence of shrubs and herbaceous vegetation after clearcutting old-growth Douglas fir in the Oregon Cascades. U. S. Dept. Agr. Forest Service Research Paper 34.



APPENDIX 1. Subjective Scales for Ground Seedbed Uniformity  
and Disturbance Within Quadrats

Ground Seedbed Uniformity

- 1 - Very uniform pattern, regular distribution of species, microtopographic variation minimal.
- 2 - Slight variation in either species distribution pattern or in microtopography.
- 3 - Noticeable variation in both species distribution pattern and in microtopography.
- 4 - Distinctly heterogeneous in appearance, irregular species distribution and composition. Microtopography differences great.

Disturbance

- 1 - Ground surface and vegetation undisturbed.  
Condition characteristic of mature forest.
- 2 - Organic (duff) layer partially removed but still covering mineral soil.
- 3 - Organic layer removed exposing surface mineral (Ae) horizon.
- 4 - Organic layer and surface mineral horizon removed, exposing second mineral (Bt) horizon.



## APPENDIX 2. Semi-quantitative and Qualitative Scales Used in Making Subjective Estimates

### Cover Abundance Scale

Symbol		Midpoints for calculation
P	Present only; cover infinitesimally low	0.01%
R	Rare; cover very low	0.1%
+	Occasional; cover less than 1%	0.5%
1	Cover between 1 and 5%	3%
2	Cover between 5 and 15%	10%
3	Cover between 15 and 25%	20%
4	Cover between 25 and 50%	37.5%
5	Cover between 50 and 75%	67.5%
6	Cover between 75 and 95%	85%
7	Cover between 95 and 100%	97.5%

### Dispersion Scale

- 1 - Regular; individuals evenly spaced.
- 2 - Semi regular; most individuals evenly spaced, some clusters.
- 3 - Random; individuals distributed according to chance.
- 4 - Semi-contagious; individuals usually in clusters.
- 5 - Contagious; individual always in clusters, no isolated individuals.

### Phenology Scale

- B Buds
- Fol In foliage
- Yel Leaves yellow or brown but attached and living



Mot	Leaves mottled; population becoming dormant
Dor	Leaves shed as litter; winter buds formed
Fl	Flowering
Fr	Fruiting



APPENDIX 3. Criteria for Restocking of Clearcut Blocks  
(Northwestern Pulp and Power Company)

Seven years after clearcutting, Northwestern Pulp and Power makes a regeneration survey on the clearcut blocks. Adequacy of natural regeneration is determined by the percentage of stocked 1 milacre quadrat, each milacre being the quadrant of a 14.90 ft. (diam.) circle. The quadrats are located along diagonals across the same cover type and topography within the clearcut block. The clusters of 4 milacre quadrats are placed at 1 chain intervals on 20 acre blocks, 2 chain intervals on 40 acre blocks, 3 chain intervals on 60 acres blocks, etc.

A stocked milacre quadrat contains 3 one year old trees, 2 two year old trees, or 1 tree at least three years old.

Provincial regulations state that stocking level must be at least 40%. The company can include up to 10% stocking to aspen in this figure, the remainder of which must be conifers. Regulations also require that a stocking of 40% or greater must be achieved within 10 years after clearcutting.

A sufficient number of conifer seedlings are planted the year following the regeneration survey on understocked blocks as as to achieve adequate stocking.



## APPENDIX 4. List of Vascular Plant Species

*Polypodiaceae*

*Gymnocarpium dryopteris* (L.) Newm.

*Equisetaceae*

*Equisetum arvense* L. 3,18,25

*Equisetum scirpoides* Michx.

*Equisetum sylvaticum* L. 21,25

*Lycopodiaceae*

*Lycopodium annotinum* L. 12,22

*Pinaceae*

*Abies lasiocarpa* (Hook.) Nutt. 2,4,5,9,10,12,20,24

*Larix laricina* (Du Roi) K. Koch

*Picea glauca* (Moench) Voss 6,7,10,15,21

*Picea mariana* (Mill.) B.S.P. 21

*Pinus contorta* Louden var. *latifolia* Engelm.

*Gramineae*

*Agropyron repens* (L.) Beauv.

*Agropyron subsecundum* (Link) Hitchc. 18

*Agrostis scabra* Willd. 7,9,10,22

*Bromus ciliatus* L. 5,21,22

*Bromus inermis* Leyss. 21

*Calamagrostis canadensis* (Michx.) Beauv.

*Cinna latifolia* (Trev.) Griseb. 15

*Elymus innovatus* Beal

*Festuca saximontana* Rydb.

*Hordeum jubatum* L.

*Oryzopsis asperifolia* Michx.

*Oryzopsis pungens* (Torr.) Hitchc.

*Phalaris arundinacea* L.



*Phleum pratense* L. 5,7,10,22  
*Poa compressa* L. 17,18,22,24,25  
*Poa palustris* L. 19  
*Poa pratensis* L. 13,20  
*Schizachne purpurascens* (Torr.) Swalkn.  
*Trisetum spicatum* (L.) Richt. 5

#### Cyperaceae

*Carex* sp.  
*Carex aenea* Fern. 7,14  
*Carex brunnescens* (Pers.) Poir. 9,14,19,20,25  
*Carex pachystachya* Cham. 20,21  
*Carex raymondii* Calder  
*Carex richardsonii* R. Br. 7,13

#### Juncaceae

*Juncus tenuis* Willd. var *dudleyi* (Weigh.) 10,21  
*Luzula parviflora* (Ehrh.) Desv. 10,17

#### Liliaceae

*Lilium philadelphicum* L. var *andinum* (Nutt.) Ker 5  
*Maianthemum canadense* Desf. var *interius* Fern. 14  
*Smilacina stellata* (L.) Desf.  
*Smilacina racemosa* (L.) Desf. var *amplexicaulis* (Nutt.) S. Watts  
*Streptopus amplexifolius* (L.) DC. 1,2,13,20

#### Orchidaceae

*Calypso bulbosa* (L.) Oakes  
*Habenaria hyperborea* (L.) R.Br.

#### Salicaceae

*Populus balsamifera* L. 5,10,19  
*Populus tremuloides* Michx.  
*Salix bebbiana* Sarg. 14,18  
*Salix interior* Rowlee  
*Salix pseudomonticola* Ball 7,13,22,25



*Betulaceae*

*Alnus crispa* (Ait.) Pursh 8,10,15,16,21

*Betula papyrifera* Marsh. 16

*Urticaceae*

*Urtica urens* L. 13

*Santalaceae*

*Geocaulon lividum* (Richards.) Fern.

*Caryophylloceae*

*Serostium vulgatum* L. var. *hirsutum* Fries 13,18,21

*Stellaria calycantha* (Ledeb.) Bong.

*Ranunculaceae*

*Actaea rubra* (Ait.) Willd. 3,19

*Clematis verticillaris* DC. var. *columbiana* (Nutt.) A. Gray

*Delphinium glaucum* S. Wats.

*Ranunculus abortivus* L.

*Ranunculus acris* L. 12,18,21,24

*Thalictrum venulosum* Trel. 4

*Sanifrogaceae*

*Mitella nuda* L.

*Ribes glandulosum* Grauer 9,10,14,18

*Ribes hirtellum* Michx. 10,20

*Ribes triste* Pall. 2,11,15,16,19,21,24,25

*Rosaceae*

*Amelanchier alnifolia* Nutt.

*Fragaria vesca* L.

*Fragaria virginiana* Duchesne 19

*Geum macrophyllum* Willd. 11

*Potentilla norvegica* L. 6,13,21,22

*Rosa acicularis* Lindl. 1



*Rubus acaulis* Michx.

*Rubus pubescens* Raf.

*Rubus strigosus* Michx. 2,3,21,22,24

*Sorbus scopulina* Greene 1

*Spiraea lucida* Dougl.

#### *Leguminosae*

*Lathyrus ochroleucus* Hook. 13

*Trifolium hybridum* L. 9,10,16

*Vicia americana* Muhl. 2,5

#### *Violaceae*

*Viola adunca* T. E. Smith

#### *Elaeagnaceae*

*Shepherdia canadensis* (L.) Nutt. 2,5,7,14,25

#### *Onagraceae*

*Epilobium angustifolium* L.

#### *Araliaceae*

*Aralia nudicaulis* L. 18

#### *Umbelliferae*

*Hieracleum lanatum* Michx. 19

*Osmorhiza depauperata* Philippi 16

#### *Cornaceae*

*Cornus canadensis* L.

#### *Pyrolaceae*

*Pyrola asarifolia* Michx. 8,18

*Pyrola secunda* L. 22

*Pyrola virens* Schweigg

#### *Ericaceae*

*Arctostaphylos uva-ursi* (L.) Spreng. 1,3,4,9,13

*Ledum groenlandicum* Oeder



*Vaccinium caespitosum* Michx.

*Vaccinium membranaceum* Dougl.

*Vaccinium myrtilloides* Michx.

*Vaccinium vitis-idaea* L. var. *minus* Lodd.

#### *Boraginaceae*

*Mertensia paniculata* (Ait.) G. Don 4,21,22

#### *Scrophulariaceae*

*Castilleja* spp. 2,14,17,18,20,21

#### *Rubiaceae*

*Galium boreale* L. 5,22,25

*Galium triflorum* Michx.

#### *Caprifoliaceae*

*Linnaea borealis* L. var. *americana* (Forbes) Rehd.

*Lonicera dioica* L. var. *glaucescens* (Rybd.) Butters

*Lonicera involucrata* (Richards) Banks 1,2,3,4,5,7,9,12,21,22,23  
1,2,11,13,20,22,25

*Sambucas melanocarpa* A. Gray 12

*Viburnum edule* (Michx.) Raf. 14

#### *Campanulaceae*

*Campanula rotundifolia* L. 4,7,11,13

#### *Compositae*

*Achillea millefolium* L. 2,13,18,19

*Antennaria neglecta* Greene, 4,16

*Arnica cordifolia* Hook.

*Aster ciliolatus* Lindl.

*Aster conspicuus* Lindl. 10,21

*Chrysanthemum leucanthemum* L.

*Hieracium umbellatum* L.

*Petasites palmatus* (Ait.) A. Gray

*Senecio indecorus* Greene, 10,13

*Solidago decumbens* Greene, 4,13



*Solidago gigantea* Ait. 3,5

*Solidago lepida* DC. 4

*Taraxacum officinale* Weber 1,10,11,19,20,22



## APPENDIX 5. List of Bryophytes

## MOSSES

*DITRICHACEAE*

*Ceratodon purpureus* (Hedw.) Brid.

*AULACOMNIACEAE*

*Aulacomnium palustre* (Hedw.) Schwaegr.

*ENTODONTACEAE*

*Pleurozium schreberi* (Brid.) Mitt.

*HYPNACEAE*

*Ptilium crista-castrensis* (Hedw.) De Not.

*HYLOCOMIACEAE*

*Hylocomium splendens* (Hedw.) B. S. G.

*POLYTRICHACEAE*

*Polytrichum commune* Hedw.





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